Measuring Net Zero:

CARBON ACCOUNTING FOR BUILDINGS AND COMMUNITIES

LEGACY DOCUMENT

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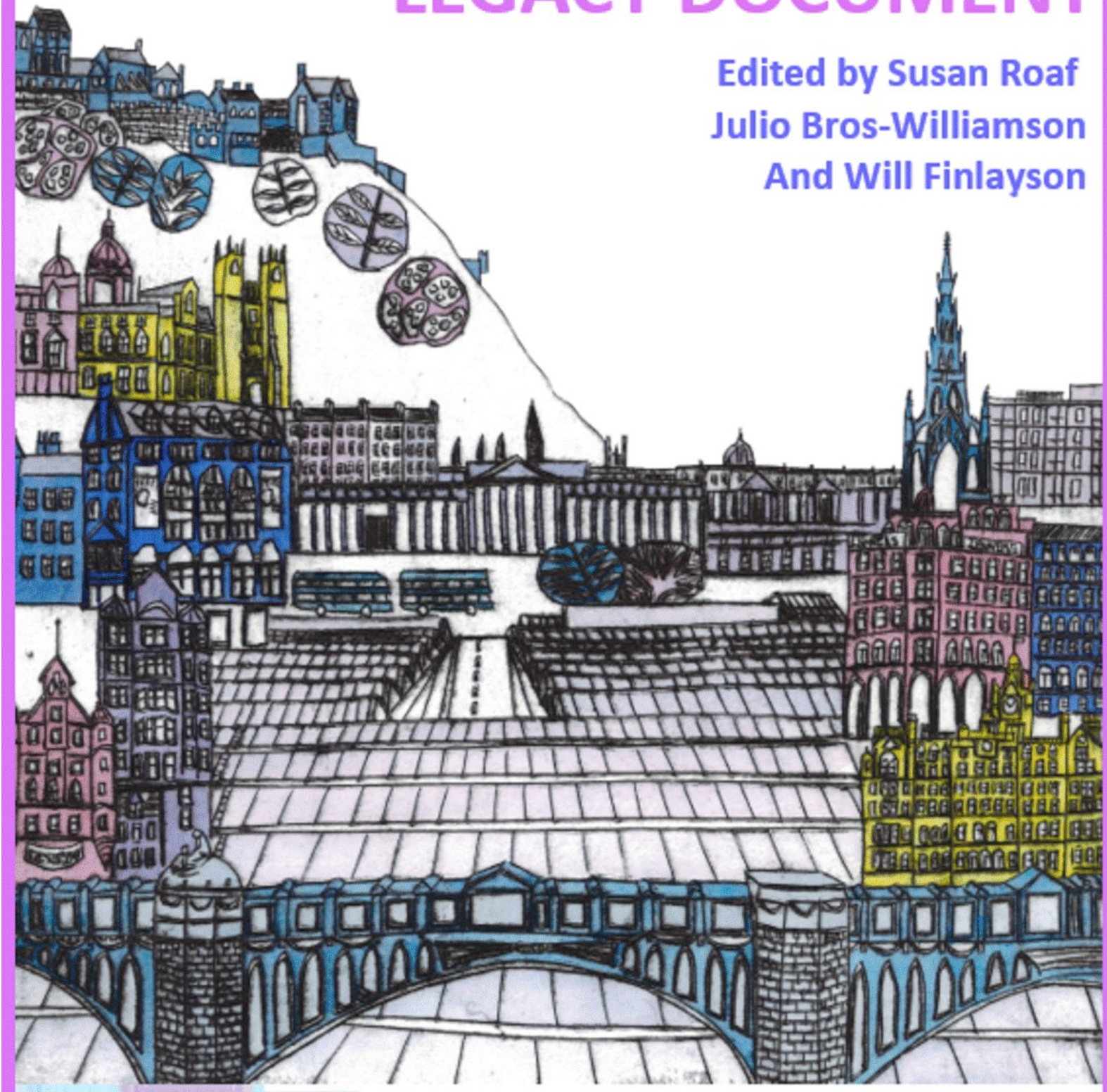

ICARB
8th International ICARB Conference 2023:
25th - 26th September 2023 Edinburgh

ICARB 2023

LEGACY DOCUMENT:

Brief Summary of and Reflections on the

8th International ICARB Conference on Carbon Accounting

MEASURING NET ZERO:

CARBON ACCOUNTING FOR BUILDINGS AND COMMUNITIES

Held at The Edinburgh City Chambers

25th – 26th September 2023

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ICARB 2023
MEASURING NET ZERO FOR BUILDINGS & COMMUNITIES

NAVIGATING THIS LEGACY DOCUMENT

The conference was attended by delegates from twenty-seven different countries, from all walks of life including politicians, academics, developers and those from the construction industry and the designing professions. The pathway to a Net Zero future is incredibly important not only to stabilise the climate but also to provide the best possible chance of managing the impacts of a heating world on global societies, economies and their environments. Many of the issues discussed are complex and can be divisive. We purposefully brought to the meeting people from many different sides of the debate to provide a safe and solution facing forum for discussion.

To ensure that some of those debates were not lost we are producing this Legacy Document, with short overviews of the contents of each session and the deliberations that followed papers and sessions. Many of the Papers are included in the **Proceedings of this Conference**. Where possible the **Power Point presentations** of speakers are also available on the ICARB 2023 website. Six of the most telling presentations are available on **YouTube** and are also linked via the website and click linked to the speakers highlighted in orange below.

Legacy Notes were taken by Rapporteurs in each session of the Conference giving an overview of what was said and the questions and discussions in each session. To access those notes just click link on the **blue session heading**s for the topics you are interested in and that will take you to the reports on the talks around that subject. As well as plenary sessions there were six specialist **Workshops** on a range of key topics where papers were presented and discussed in more detail.

Finally, there is a report on the last **Panel Session** that provided an opportunity for five speakers from around the world to share their thoughts and captured the comments of many who contributed there. A final section of **Reflections** from delegates sent in after the conference captured thoughts on what had been included and excluded from the conference.

We hope that by sharing this Legacy Document with you it may help to shine a light on one particular aspect of the Net Zero Challenge that is important to you or just give an overview of the scale of the whole challenge of achieving and measuring Net Zero in the Building and Communities of the world. We hope also that the documents generated by the conference may help some of you not only with understanding the subject but also when researching and teaching it.

Thank you for your interest. This is not a finely honed or edited or a consistently reporting document. It was produced with our excellent international team of Rapporteurs. We do hope it provides a useful aide memoire for delegates and assistance for all in thinking through these complex and vital issues.

Click Link on the Blue Headings to go straight to the Legacy Notes for that session.

SESSION 1: WHO DECIDES AND WHAT COUNTS?

Patrick Harvie, the Scottish Minister for Net Zero on Scotland's Heat transition – outlining the national heat policy and the thinking behind it.

Stephen Garvin, Head of Building Regulations for the Scottish Government on how energy and emissions reductions are achieved through regulations.

John Forster, CEO of the Forster Construction Group – on the construction industry's view of emissions reduction in practice focussing on the many use of solar technologies in Scotland.

Eliza Hotchkiss of the US National Renewable Energy Laboratory questions whether Net Zero thinking (mitigation) is all very well as the climate crisis grows - but does it result in less resilient buildings? (adaptation).

SESSION 2: HOW FAR CAN GRID DECARBONISATION HELP WITH NZB TARGETS?

Paul Dorfman the Chair of the Nuclear Consulting Group outlines how nuclear can, or cannot contribute in reality to decarbonising the grid

Marius Peters of the Helmholtz Institute, Nuremberg shows how solar can and is contributing but you need to do the calculations of carbon reductions very carefully

Camilla Thompson of the University of Edinburgh then gives an overview of the potential of using CCS with waste to energy processing plants

Angela Hepworth of DRAX outlines the progress with the BECCS protocol, making the point that whatever the system in place you need very careful and consensual and correct accounting

SESSION 3: PLANNING AND COSTING THE ENERGY TRANSITION

Mark Jacobson of Stanford University – presents his own take on how to achieve Net Zero in practice in his talk on transitioning the world to 100% clean, renewable energy and storage for everything.

Jimmy Jia of the University of Oxford - in this talk will explore the challenges of accurately accounting for policies during their development and the barriers to doing so.

SESSION 4: NET ZERO POLICIES – TIME TO GET REAL

Prashant Kapoor of the IFC / World bank has been working with major cities around the world on emissions reduction strategies and have a good handle on what works. He will share with us his take on the need for knowledge, political will and finance to make change happen in reality.

Jonathan Porritt of Forum for the Future pioneer and environmental champion queries why so little in being done now when we know what has to change in the policy fields to transition to Net Zero.

SESSION 5: HOW MUCH DOES EMBODIED ENERGY REALLY MATTER?

Rolf Frischnecht of Treeze, Switzerland - describes the extent to which construction materials shape the embodied energy in and the environmental footprint of buildings.

Simon Armstrong of DRAX - then looks at the life cycle and sustainability issues around the timber used in the UK for biomass generation that provides operational energy for buildings.

Alice Moncaster of the University of the West of England looks at how the idea of Embodied Energy espoused by designers translates into meaningful practice in the search for Net Zero buildings.

Ambra Guglietti of VELUX – uses the building of the Living Places project in Copenhagen to show how the theory and policies was used there by designers and describes some challenges in doing so.

SESSION 6: NET ZERO ENERGY STANDARDS – HOW DO THEY ADDRESS SUFFICIENCY?

David Partridge, the Chair of the UK's Net Zero Carbon Building Standards Board outlines progress so far on the new UK net Zero Buildings Standard and the challenges faced in getting this far.

David Overby of Ball State University, USA reflects on the tools to hand in the USA to actually design Net Zero Buildings and questions if they take into account the scale of the run-away climate change we are facing, suggesting possibly we should be looking at 'Passive Survivability' buildings instead.
Rahman Azari of Pennsylvania State University, USA argues that tackling embodied carbon will provide a reliable pathway to achieving net-zero emission aspirations for the built environment.
Timothee de Toldi of Bouygues Immobilier SAS, France – presents a study on how important now, and in the future, high levels of thermal mass are for both adaptation and mitigation of high temperature impacts indoors showing occupants will increasingly suffer thermal stress without expensive AC and use more energy and produce more GHGs if they do use it.
Ulrike Passe of Iowa State University, shares her work that demonstrated that free cooling from air movement from natural ventilation and fan use plays a critical role meeting Net Zero targets.

SESSION 7: GLOBAL INSIGHTS INTO NET ZERO BUILDING FUTURES

Norhayati Mahyuddin from the University of Malaya, Malaysia – describes an energy efficient retrofit of a nearly zero energy educational building in Malaysia, showing strategies for a hotter tropical climate, using the IESVE simulation tool developed in Scotland.
Vanessa Gomes from the University of Campinas, Brazil – presents innovative thinking on the challenges of creating low emissions building that can be usefully naturally ventilated and include low carbon thermal mass. Their paper shows two novel strategies for carbon removal in building materials involving bio-based materials and the use of mineral carbonation techniques to minimise emissions.
Rajan Rawal of CEPT University, Ahmedabad, India – shows that radical reduction in office energy consumption and emission reductions are possible by simply opening windows to naturally ventilate and using fans in hot dry and hot humid climates. The aim is to reduce to the number of hours that mechanical systems are necessary for comfort. The savings possible by doing that are significant.

THE 5 WORKSHOP SESSIONS – DETAILED INVESTIGATIONS OF SPECIFIC ISSUES

WORKSHOP: BUILDING METRICS AND MODELS

Rajat Gupta and Matt Gregg of Oxford Brookes University, UK Novel local energy mapping for assessment of household capabilities for low carbon technologies,
Christina Francis spoke for Bjarn Gudlaugsson et al. of the University of Edinburgh spoke on the Carbon accounting using multi-criteria assessment for SLES: challenges and opportunities
Mahsa Sayfikar and David Jenkins of Heriot Watt University, Scotland spoke Variations of input parameters in EPCs calculation methodologies across European countries
Hamza Hamida, Thaleia Konstantinou et al. of the Technical University, Delft, Netherlands spoke of Solar cooling integrated façades: towards investigating product applicability. This raised the issue of how to account for potential carbon reductions of novel technological approaches at the design stage using convention assessment methods.
Oz Kira, Julius Bamah et al. of Ben Gurion University of the Negev, Israel showed how remote sensing-based frameworks were being used to quantify city-level carbon fluxes in urban green infrastructures in Israel.

WORKSHOP: BEHAVIOURS AND DECISION SUPPORT

Angela Rosa-Garcia, Jessica Fernandes-Aguera et al. of the University of Seville spoke of Potential of natural ventilation in heritage buildings: a case study at the Casa Fabiola Museum, Seville.
Ulrike Passe and Fatemeh Yazdandoust of Iowa State University, USA outlined decision support for building design to optimise daylight and natural ventilation in an urban context.
Xiaonan Li and Qingchang He of the University of Pecs, Hungary showed how green roof and PV panels of public buildings for energy savings and to alleviate climate change.

Luke Gooding and Sonja Oliveira of the University of Strathclyde, Scotland presented a review of the evidence on visualising carbon in the design and delivery of buildings.

Koran Kandilci, Duygu Aral et al. of İzmir Metropolitan Municipality, Turkey described work towards a city sustainability hub: advancing urban sustainability governance through participation.

WORKSHOP: WHOLE LIFE AND EMBODIED CARBON ACCOUNTING

Rosemary Fieldson and Ozlem Duran of the University of Lincoln, UK, presented a study on the Impact of location selection on a whole life carbon of a multi-national manufacturing facility.

Paola Seminara, Andrew Livingston and Julio Bros Williamson of the University of Edinburgh show a study of the Carbon evaluation and hygrothermal performance comparisons of stone wall retrofits.

Bofa Udisi, Fatma Osman, Mark Gorgolewski et al. of Toronto Metropolitan University, Canada described a study on quantifying the embodied emissions of building envelope systems in Toronto.

Joe Sanchez, Bamdod Ayati, Harry Sumner et al. of the University of East London, UK presented their work on embodied carbon performance gaps in timber production.

Bruce Haglund of the University of Idaho, USA shows a case study: a low-carbon, mass timber arena.

WORKSHOP: NET ZERO ENERGY COMMUNITIES

Laura Moldovan, Sonja Oliveira and Ombretta Romice of the University of Strathclyde, Scotland described their exercise on accounting for impacts of energy storage systems in urban contexts - a review of the evidence.

Iain Andrew Struthers, Andrew Lynden et al. of the University of Edinburgh explained the benefits of achieving zero carbon communities by co-location of marine renewable energy.

Matthias Haas of the Zurich University of Applied Sciences, Switzerland had his paper presented by Sue Roaf on optimising returns on roof top solar installations in a paper titled: How circular is a renewable energy supply in existing buildings ?

Tika Ram Pokharel of Tokyo City University, Japan contributed a paper on energy use, CO2 emission, and emission reduction potential of cooking fuel substitution in Nepal.

WORKSHOP: NET ZERO UNIVERSITY CAMPUSES

Robert Koester of Ball State University, USA showed how their university are leveraging the voluntary carbon market to invest in deeper carbon reduction.

Deirdre van Gameren and Andy van den Dobbelsteen of the Technical University of Delft,Netherlands showeded their excellent work there on creating the sustainable campus - working towards a carbon neutral university.

Julio Bros Williamson of the University of Edinburgh showed how they are managing Net Zero strategies for a complex university estate.

Sara Dorregaray-Oyaregui, Christina Muñoz Corsini and Maria Clouet of the University of Navarra, Spain described measuring the carbon footprint of the University of Navarra, Spain

WORKSHOP: ADAPTIVE OPTIONS FOR THERMAL COMFORT

Romina Rissetto of the Karlsruhe Institute of Technology, Germany with **Gesche Heubner** of University College London described their study of mixed methods approach to understand occupants' acceptance and use of a personal ceiling fan.

Kai Zheng, Yu Fang Oh and Aceson Han of Singapore University of Technology and Design showed the benefits of reducing operational carbon while maintaining thermal comfort through evaporative cooling.

Seyed Hooshmand, Mino Rodriguez et al. of the Karlsruhe Institute of Technology, Germany described the effects on skin temperatures of local radiant heating devices for different body parts.

Bernadette Csaszar, Oliver Kinane and Richard O'Hegarty of University College Dublin, Ireland discuss in their presentation the tricky challenge of balancing aesthetics, operational energy and embodied carbon emissions: analysis and guidance.

Samantha McCabe and Catriona Kinghorn of Oberlanders Architects LLP, UK, two architects using a real case study building describe how they are continually jumping the hurdles of a true Net Zero construction.

FINAL PANEL DISCUSSION: WAYS FORWARD FOR NET ZERO BUILDINGS

The policies, strategies and regulations we have applied to date are not working as the gap between GHG emissions targets and achievements in reality are widening. Radical new directions are needed and the Panel will share their thoughts on what they might be, taking in views from the audience.

Vanessa Gomes	Brazil	**Timothee de Toldi**	France
Rolf Frischnecht	Switzerland	**Julio Bros Williamson**	Scotland
Daniel Overby	USA		

REFLECTIONS: A MISCELLENY OF THOUGHTS FROM THE VACATED FLOOR

The submitted after-thoughts of some of the delegates have been integrated into a narrative that may hopefully shed some new light on the past, present and future of approaches to, and actions around, the challenge of radically reducing Greenhouse Gas emissions from our buildings.

SESSION 1. WHO AND WHAT COUNTS?

Chairs: Sue Roaf, Heriot Watt University and Julio Bros Williamson, University of Edinburgh

Reporter: Mahsa Sayfikar, Heriot Watt University

Sue Roaf introduced the confQerence and the issues that will be addressed in the first session, reiterating the urgency of climate change and actions for decarbonisation. She emphasized that efforts to reduce carbon emissions have had little impact so far, and the importance of looking at what zero carbon policies work and how they should be costed.

Julio Bros Williamson also welcomed the audience and explained about his pragmatic approach towards net zero research. And then proceeded to provide an overview of the session speakers.

The Heat Transition – Scotland's Progress

Patrick Harvie Scottish Minister for Zero Carbon Buildings and Active Travel

Patrick Harvey started with criticizing the recent announcement from the UK prime minister regarding a U-turn on decarbonisation plans. While it's a big challenge to get the necessary regulations in place to achieve net zero goals, the announcement about delaying heat transition goals was disappointing. However, the even bigger danger is the denial of climate change in the media and it's important to note the changing of policies undermines the efforts to bring people towards the net zero goals.

Scotland has to reduce emissions from heating by 68% by 2030 to achieve its goals which is challenging due to the current building stock. All homes should reach EPC C by 2033, which is achieved by improving building fabric. However, we need to use low emission heating systems as well, which for many homes it means using heat pumps and heat networks. We are installing four or five thousand heat pump units per year. However, we need to rapidly increase these numbers, reaching a few hundred thousand units per year by the end of this decade. This requires sending clear signals to the industry about our intent, and announcements similar to the recent one weakens this.

The Scottish government is providing funding for the heat transition to both households and businesses. The heat transition should not be seen only as a challenge, but also as an opportunity to build better relationships between consumers and providers such as utility companies, financial institutes, etc. to provide high quality careers and continue innovation. Public engagement is a big part of the heat transition, and the mixed signals from the UK government is not helpful in that regard either. The Passivhaus equivalent bill was also discussed briefly. In addition, there are consultations going on about modification of EPCs, to ensure they provide the information that the users need. The most important take away now is for everyone to try to encourage the public to get on board with the decarbonization plans, since that's imperative in achieving the next steps.

Q1. was asked about the Passivhaus bill and why the green party didn't support it. The answer pointed out that they changed their views and now acknowledge the fact that the bill can be built through the building standards and the existing infrastructure. Also, across political parties there's consensus in achieving this goal.

Q2 was regarding how can EPCs be used to inform people about how to improve their properties. Patrick Harvie mentioned his work in the public health sector and how difficult changing in people's behaviour is, in particular regarding personal matters such as their living spaces. It requires adequate

information provision, and ensuring people that it is possible to make such changes and providing enough examples of those changes in the society.

Q3. was asked regarding the lengthy waiting times for installing insulation in buildings in Scotland. Patrick Harvie emphasized the government's goals regarding providing new homes, and the challenges of retrofits. Different retrofitting approaches must be adopted for different homes. The critical requirement in terms of skills, and supply chain, is sending a clear signal to the industry that these efforts are worth their while and the move towards decarbonizing the building stock is happening. Which will lead to the industry investing and making sure retrofits will happen.

Q4. was about consumer protection regarding retrofits going wrong. The minister's answer pointed the fact that it depends on legislations on the UK level, and the Scottish government must work with the limits imposed by that, while asking for these issues to be addressed. Another question was regarding Scotland's solar policy. It was explained that there is a solar vision under the energy strategy which will be published soon (no date).

Implementing change to energy performance and emissions through building standards - Stephen Garvin Head of Building Regulations, Scottish Government

An introduction was given on the Scottish Building Act evolution for the international audience. In Scotland, the building standards are pre-emptive and any changes in buildings must get permission from the local authorities. There were changes in Section 6 which were introduced in February. Responses to consultations for these changes were surprisingly high in numbers. New "delivered energy targets" are introduced which is more representative of the energy consumed than the previous "final energy targets". New regulations will make buildings more fabric efficient to be prepared for installing heat pumps or using heat networks. Some changes in the regulations include changes to exporting on-site power generation. In addition, heat networks are now considered zero direct emissions solutions, therefore there is no emissions target for buildings using heat networks, and only a new energy target is imposed.

Backstop U-values are improved in the new version, but thermal bridging details have not been updated. From next year the option for combustion boilers will be removed. Air tightness tests are now mandatory for new homes as well, and the low-pressure pulse method has been recommended as the reliable measurement method. The Passivhaus equivalent bill was briefly explained, and it was emphasized that is not just an energy standard, but it also concerns environmental aspects and the quality of construction. One important challenge to note is moving from double glazing to triple glazing.

Building in solar, more than just a transition John Forster Chairman of the Forster Construction Group, UK

John Forster gave an introduction about the company and its history. He then proceeded to compare the cost of wind and solar energy and how solar is more cost efficient. Since we are moving to electrified homes, it is important to think about integrating solar energy generation and storage in homes for reducing cost and transitioning to net zero.

He also mentioned the importance of the workforce and training necessary for solar installation. It was reiterated that the industry is already making the necessary changes, however it is vital to give them clear signals to encourage the move towards Net Zero, which is not the case at the moment. Also, in order to help with transitioning to electrifying heating and the new Passivhaus equivalent bill coming into force, it is necessary to increase solar roof installations.

Does Net Zero address the seriousness of the climate challenge?
Eliza Hotchkiss NREL, USA

In order to achieve US net zero goals, it is necessary to take steps in the following key markets: buildings efficiency, renewable energy, electrification of transport, clean fuels, and carbon capture. This talk was focused on the building efficiency. The new power grid with prosumers and storage potential is posing new challenges but also provides new opportunities. In this landscape, it's very important to consider resilience. This research studies the energy efficiency measures in buildings that also increase human survivability under extreme conditions and how these can impact the building codes and standards. The researchers modelled buildings following the current codes as well as buildings following the Passivhaus standard, to study how they withstand extreme conditions. Their results showed indoor comfort levels increased for buildings modelled with Passivhaus standards. Mortality numbers also decreased when using these standards, which shows that passive resilience needs to be incorporated into energy standards to save lives.

Who decides and what really counts? Panel Discussion

Q1. was asked of Eliza Hotchkiss about how did they consider Passivhaus during a power outage? (Since it requires mechanical ventilation.) She answered that they controlled the Energy Plus model manually. They are also adding occupant behaviour features in the future to include window opening patterns.

Q2. was asked regarding making openable windows mandatory in all buildings, since a lack of operable windows during hurricane Sandy in the US caused many serious problems. And the answer confirmed operable windows are a key factor in survivability.

Q3. was asked about whether we are learning from other countries in terms of policies and standards around EPCs? (For example, using research results from the clusters of Horizon projects on next generation EPCs). Stephen Garvin answered that the Scottish government is engaging with other countries. They also have their own research programs focused on this topic and there is also a lot of information exchange between different countries. Organizations such as BE-ST are also very useful in translating research into innovation.

Q4. focused on the fact that builders are switching to installing heat pumps rather than installing solar PVs and how that can be stopped. John Forster explained that we need to consider which technologies lower the cost of energy for consumers in order to make Net-Zero transition affordable. A report published by Loughborough and Cambridge showed a great potential for UK homes to become income and energy generators using solar energy. It is important to note the role of micro renewables in achieving Net Zero and harnessing the benefits of the flexibility in the future markets.

SESSION 2: GRID PATHWAYS AND PROTOCOLS TO NET ZERO

Chair: Professor Stuart Haszeldine, University of Edinburgh
Rapporteur: Alasdair Reid, Napier University

Background

In the quest to combat climate change and reduce greenhouse gas emissions, the concept of achieving "net-zero" in buildings has emerged as a crucial and ambitious goal. Net-zero buildings are designed to balance the amount of carbon emissions they produce with the amount they remove from the atmosphere, effectively having no net impact on the climate. To achieve this balance, innovative strategies like carbon capture and biomass utilization play pivotal roles. Carbon capture technologies aim to capture and store carbon dioxide emissions generated within buildings, while biomass utilization involves harnessing renewable materials such as wood or plant-based products to minimize carbon emissions and contribute to sustainable construction. In this era of climate

urgency, integrating these practices into building design and construction has become essential, not only for reducing the environmental footprint of the built environment but also for advancing the transition towards a more sustainable and eco-friendly future.

Session Presentations and Discussions

In the mid-morning session 'Grid Pathways and Protocols to Net Zero,' the first speaker was **Dr. Paul Dorfman from the University of Sussex.** His presentation was titled 'The Role of Nuclear in a Low Carbon Future - Do the Metrics Matter?' Dr. Dorfman began by emphasizing the IPCC's position on carbon reduction targets, as outlined in their 2023 summary report. The IPCC unequivocally stated that renewables are ten times more effective than nuclear at mitigating CO2 emissions, specifically in relation to 2030 targets. The IPCC's analysis, based on 175 peer-reviewed articles, indicated that solar and wind power have the potential to reduce 8 billion tons of annual CO2 emissions by 2030, equivalent to the combined emissions of the US and EU.

Given this context, along with the significant capital costs and timeframes involved, Dr. Dorfman raised questions about the efficacy of the UK government's continued support for nuclear projects

The second presentation, titled 'Carbon Metrics for PV Systems,' was delivered by **Ian Marius Peters from the Helmholtz Institute** in Erlangen, Nuremberg, Germany. It investigated the energy consumption and carbon emissions of photovoltaic (PV) cells during both the manufacturing and operational phases. The presenter used simple mathematical calculations to assess the energy consumption of PV modules during operation and manufacturing processes. The following key points were confirmed:

- Even in less sunny locations, such as Edinburgh, PV modules produce more energy than they consume for production.
- The Intergovernmental Panel on Climate Change (IPCC) recognizes solar panels as the most effective way to reduce carbon emissions, both in terms of potential and cost.
- Solar panels can make a significant contribution to decarbonizing the British Isles.

In conclusion, due to the carbon-free performance of PV modules, they represent the most cost-effective solution for achieving zero-emission buildings.

This was followed by another presentation titled 'Reliably Accounting for Negative Emissions of Waste-to-Energy with Carbon Capture and Storage' **by Camila Thomson from the University of Edinburgh**. This study provided a comprehensive review of existing analyses of carbon reduction using Waste to Energy (WtE) with Carbon Capture and Storage (CCS). The author discussed the current challenges in understanding its role in the transition to a Net-zero economy within the context of the circular economy. It was mentioned that there are benefits to approaching WtE with CCS, but the question remains as to how to properly account for the negative emissions resulting from the functional units.

The fourth presentation on 'Carbon Accounting Standards for BECCS' was delivered by **Angela Hepworth from Drax,** a bioenergy company with the ambition of becoming the world leader in producing carbon removals from bioenergy. Drax aims to have 14 million tons of carbon removals online by 2030. The presentation covered:

- The urgent need for carbon removal and the challenges associated with it in the absence of embracing carbon removal technologies.

- Bioenergy Carbon Capture and Storage (BCCS), which starts with sustainably sourced biomass, including biomass from sustainable forestry operations and waste from the timber industry.
- The procedure of BCCS as a successful carbon removal solution, involving capturing CO2 from the atmosphere (through trees, a power station, and a pipeline) and permanently storing it in geological storage.

The presenter concluded by summarizing the benefits of BCCS technology as a permanent, high-integrity carbon removal solution meeting high sustainability standards. BCCS was highlighted as a scalable and cost-competitive technology compared to other solutions, and it is already in use in North Yorkshire, UK, where it has proven to be effective.

Questions for the Presenters and the Closing Discussion

Q1. Does the 2.7 kg/kWh carbon emission per PV module include the embodied carbon associated with the balance of the system, such as the controller, battery, charger, or any other necessary equipment for the PV system?
*Response from **Ian Marius Peters**: The 2.7 kg/kWh of carbon dioxide represents the carbon emissions solely from the conversion of silicon dioxide into silicon for the PV module.*

Q2. Regarding the negative externalities, unintended consequences, and internal radiations, is there any information about the health implications of dioxin, a byproduct of incineration measured in ng/m³, that may not have been explicitly mentioned?
*Response from **Camila Thomson:** The analysis primarily focused on life cycle assessment, but the presenter agreed that it would be worthwhile to explore the use of waste-to-energy and CCS as an alternative to recycling. Further analysis of these systems and their consequential impacts is needed.*

Q3. Can you explain your perspective on the civil-military nexus, with regard to the UKs nuclear programme?
*Response from **Paul Dorfman**: In response to this question, he stated that both he – and he suspects, the wider general public - are ambivalent about abandoning military nuclear capability, especially given the nature of the current war in Ukraine. However, he states that both civil and military nuclear programmes are clearly entwinned, citing work of fellow academics at the University of Sussex. He finished by saying that military nuclear capability could be 'ring-fenced' whilst relinquishing civil nuclear programmes.*

Q4. Given that energy demand is dynamic, and nuclear is designed to be a base load, it doesn't really work with renewables that are fluctuating. What you want is a base load of renewables and something else to compliment that - which nuclear doesn't do - so the two sources aren't compatible. What are your thoughts on that?
*Response from **Paul Dorfman**: renewables will do the 'heavy lifting' with regard to achieving net zero. The nuclear can be used for powering up and down, but it is completely unaffordable. The economics of powering up and down simply do not work.*

Q5. Is anyone looking seriously at the recovery of heat from nuclear?
*Response from **Paul Dorfman**: heat recovery from nuclear was a marginal issue - and not a key issue for consideration.*

Q6. As mentioned in the presentation, the use of machinery for farming and harvesting biomass materials would be allocated to the land use sector. Therefore, from a life cycle assessment point of view, where does transportation fit in here?

*Response from **Angela Hepworth**: The biomass itself is classified as zero carbon. The carbon impact of harvesting, such as cutting down the trees, is accounted for in the land use sector. However, this does not cover the supply chain emissions associated with it. Currently, these supply chain emissions represent about 10% of the carbon savings achieved through bioenergy as a technology. While significant when compared to the emissions from burning coal or gas, they are considered negligible in the context of the overall carbon removal process.*
These supply chain emissions are accounted for in our methodology when calculating the net negative product for carbon removals. In our calculations, we start with gross removals but then deduct emissions associated with transportation, machinery, and processing before arriving at our statement of the net climate benefit that BCCS provides

Q7. As mentioned in the presentation, the material for biomass is sourced from the USA and Canada, and the land use is accounted for in the USA and Canada. How can you make this a UK carbon-neutral technology?
*Response from **Angela Hepworth**: The carbon emissions associated with harvesting the biomass are accounted for in the USA, and the carbon removals are credited there. This follows a standard accounting practice based on where the technology is developed. Therefore, the country where the carbon removal technology is located is the one that claims the benefit of the carbon removal. With ongoing international discussions about carbon trading, both countries and companies have the ability to trade carbon removals. This allows us to develop projects in locations where they are most effective. Different countries may have various technological advantages, creating a system for global trading between countries.*
***Comment from audiences:** The IPCC definition was originally intended for small-scale forest harvesting and may not be suitable for this purpose. It doesn't make sense to hold both Canada and the UK accountable for carbon emissions from a forest that was closed down while storing carbon in the UK, supported by British taxpayers and the government. This appears to be double counting; it should be allocated to one location or the other, not both.*

Q8. According to the presentation, we're directing carbon through pipelines to be stored under the North sea, is this correct?
***Response from Angela Hepworth**: The UK government has recognised the need for carbon capture and storage networks to achieve negative emissions and address emissions from industrial processes, including gas fired power generation. We are working to develop multiple networks across the UK to capture carbon from these processes and store it permanently in geological storage beneath the North Sea.*
***Response from Camilla Thomson**: The UK is copying what has been done in Norway, where the carbon goes by pipeline to the either oil or gas reservoir in the North Sea.*

Q9. In light of the technologies presented in the third and fourth presentations, what are the long-term resilience considerations in the context of climate change from a biosphere perspective? With current operations in the UK sourcing biomass from halfway across the world, how do you envision the long-term resilience of this technology?

***Response from Camilla Thomson**: One consideration we are addressing is whether the process of growing a tree, turning it into cardboard, and then burning it negates the environmental benefits of using the cardboard box in the first place. However, we've concluded that our current analysis may not be comprehensive enough, potentially missing system-wide impacts. Implementing waste-to-energy and CCS could inadvertently incentivize increased waste production and material consumption. Without accounting for these system-wide effects, our conclusions may be skewed. Consequential Life Cycle Assessment (LCA) requires us to consider time series and system-wide effects, including cause-and-effect pathways.*

Response from Angela Hepworth: *In terms of the environmental impacts of BCCS technology, one counterintuitive aspect is that, from a carbon perspective, managed forests are more effective at generating carbon savings than leaving trees untouched. However, this efficiency depends on having proper safeguards in place for the sourced forest. We've detailed this in our methodology, particularly regarding the types of forests that can be used. For example, our methodology prohibits sourcing from primary forests or areas of high biodiversity.*

SESSION 3 - PLANNING AND COSTING THE ENERGY TRANSITION

Chair: Peter Strachan, Robert Gordon University, Aberdeen
Rapporteur: Magdalena Blazusiak, Robert Gordon University, Aberdeen

The workshop was introduced by the Chair as a session detailing what is required and who needs to lead the energy transition.

Mark Jacobson from Stanford University on Transitioning the World to 100% Clean, Renewable Energy and Storage for Everything, discussed drivers for and enablers of the transition from fossil fuels to renewable, clean energy that can be achieved at micro and macro scale across the world utilising Wind, Water and Solar (WWS) Solutions.

The author described the risks of the reliance on carbon capture and the effects on the increase of carbon dioxide diverting renewable energy used for carbon capture from replacing coal and gas used for heating, thus increasing air pollution, mining and fossil infrastructure. The case study of the carbon capture facility for ethanol refinery demonstrated that infrastructure investment, fuel and upfront cost of carbon capture brings little to no benefit when compared with investment in Electricity from Wind and Battery Electric Vehicles (BEVs).

Alternative of nuclear power was described as not viable alternative to solar and wind power due to the comparably high CO_2 and pollution factor, time between planning and operation, capital cost and risks such as weapon proliferation, meltdown, waste and mining.

The presentation then explored how solar PV panels with battery storage and renewable heating and cooling solutions can assist the domestic sector transition from fossil fuels. The author explained the demand reduction of the energy from the grid utilising renewables and efficiencies of the WWS technologies, providing over 55% reduction to the estimated energy demand in 2050. This would also allow for reduction in land use by transitioning to WWS as opposed to use of fossil fuel energy. Author demonstrated that the demand response and grid reliance can be met with 100% WWS and energy storage in 2050 scenario with a capital cost payback time of the transition to WWS clean renewable technology and storage inclusive of the fuel energy, health, climate and social cost within 5-6 years.

In summary, the transition to WWS energy could create more jobs, reduce land use for energy generation, avoid air pollution deaths, slow and reverse global warming, retain stable grids worldwide and reduce annual energy costs as compared to fossil fuels.

Jimmy Jia from the University of Oxford presented 'Merging the metrics for finance and carbon accounting'. The presentation was introduced describing the opportunities of optimising energy in order to reach a carbon outcome. The author explained the difficulty of current accounting for Greenhouse Gas (GHG) Emissions caused by the discrepancies between methodology for the accounting for Global and National GHG Emissions based on IPCC, the Corporate GHG Emissions based on Life Cycle Assessment (LCA) methodologies and the financial systems reporting, which are

based on the financial statements and financial accounting. Ensuring achieving good environmental outcomes through investment should be based on the principles of accounting from the financial sector, such as the ability to make comparative assertions and following the rules of decision-usefulness.

It has been highlighted that the GHG Protocol does not follow the rules of the financial decision usefulness and by allowing choice of the emissions factor in 1,2 and 3 scope emissions introduces non comparability of data. The condition for comparability can be achieved by accounting for activity data separately from Emission Factor and by use of Combustion Emission Factor, thus accounting for energy before accounting for carbon. In addition, to meet the comparability criteria the time accounting between LCA and financial accounting needs to be synchronised, by use of Double Entry Bookkeeping (DEBK) to synchronise time and accrual accounting to accumulate energy/carbon footprint.

In accounting, Double Entry Bookkeeping introduces cash, inventory and expenses in addition to debit and credit (Single Entry Bookkeeping). For a comparable carbon accounting based on the financial model, the author proposed introduction of Intrinsic, Embodied and Operational Energy to the already accounted for Inflow and Outflow, allowing for alignment between financial and energy accounting methodology, presented in the form of energy balance sheets representing flow of energy and carbon.

The presentation explained the definitions of the Intrinsic energy as the amount of stored energy, Operational energy being the energy consumed and the Embodied energy which was the energy consumed in the past from which one receives energy-related benefit in the future. The Energy Asset Stack can be used to determine flexibility of use and assist in modelling of the Energy Models and investment options with consideration of the End-of-life options.

The research developed three conditions for comparability to provide metrics useful for the financial sector. Additionally, provision of energy balance sheet with double-entry bookkeeping and carbon balance sheet applying the emissions factor to the energy balance sheet can allow for improved strategic, comparative decision making and forecasting.

Q1. related to oversimplification of the complex system in output subsidy in terms of function and loss, opportunity costs and negative externalities, such as pollution.
Jimmy Jia answered that the emission factors are represented per gas, separating each GHG, which can be presented in parallel, with common emissions factor and a combined output of metrics in balance sheet with the common data of energy provider. The main focus and purpose of the research is comparability of data, rather than provision of solution to reduce GHG emissions.

SESSION 4 - NET ZERO POLICIES – TIME TO GET REAL

Chair: Angela Hepworth, DRAX
Rapporteur: Magdalena Blazusiak, Robert Gordon University, Aberdeen

The Chair introduced **Prashant Kapoor** as an expert in bioclimatic design, leading programme transitioning cities to net zero carbon. The presentation titled 'Navigating the path to Paris aligned carbon emissions the triad knowledge, political will and finance in transforming cities' focused on the delivery of city-wide green development with the assistance of assessment tool allowing evaluation of investment options.

The EDGE online tool allows the developers to gain understanding of alternative solutions and technologies, optioneering of design baseline with consideration of the financial implications in order to scale up green building investment and allow for financial comparison against the misconception of actual green building solution cost.

Both investment and policy driven changes can enable green development at the city scale. Evidence based learning allowed for the development of the Investment Planning Tool for Cities - IFC's APEX tool, collecting data from cities including transport, built environment, waste, water and

emissions. This allowed for collection of data to assist individual cities in the investment planning and comparison of options for future investment and comparison of performance between cities within the database. The tool enables instantaneous result in the estimation of green investment potential on energy demand and carbon emissions as compared to the current data, providing quantitative insight into Green Cities Action Plans. The Apex tool can also assist in the identification of funding, investment inclusive of R&D and public sector involvement and property tax linked financing. The author described the model of sustainable building bonds as an innovative financing initiative, incentivising policy driven decisions and performance-based initiatives.
The summary of the potential of the tool to assess investment was underlined by several key issues that need to be resolved by individual cities such as the methodology for evaluation of the path to achieve the targets and the necessity for private sector involvement in the financing models, predominantly in the emerging markets. The tool is used primarily for the developing cities.

Jonathan Porritt talked about the policy, the requirement for the emergency response to the crisis and consideration of conservation as the quickest, cleanest and the most practical source of energy. The talk went on to recognise the EU investment into renewables as a direct result of the war in Ukraine and the decision of the EU countries to immediately reduce reliance on oil by nearly 50%. The UK took a different route without significant commitments to reduce reliance on fossil fuels. Jonathan described concerns over the recent climate induced disasters and their financial implications, ecosystem damage and scientific evidence that is not being used to inform policy changes and sufficient response to the climate crisis, with UK Government scaling back on the Net Zero targets, including improvement to energy efficiency in rented accommodation. The concern was over the Government prioritising profit and growth over policies aiding green development and investment aligning with the benchmarks to deliver Net Zero Carbon and effective energy efficiency in the built environment. The reflection ended on the question of the responsibility of individuals in the work of researchers and campaigners.

Q1. Sue Roaf asked if and why energy sufficiency as a concept is so difficult to design in, with engineered services solution preferred to passive measures, especially in terms of ventilation. *Prashant Kapoor* commented on the difficulty of balancing the design for resilience with the provision of natural ventilation in commercial building sector.
Jonathan Porritt raised concern over capitalist economy directing the choices of designers in profit driven markets.
Prashant Kapoor added the comment on the 'impatient capital', with the investors willing to spend money on interventions that can be easily identified and seen.

Q2. from the audience concerned the issue of negative press increasing misconceptions of the low carbon solutions, energy efficiency measures and the climate emergency.
Jonathan Porritt expanded on the importance of the central Government responsibility to safeguard and support health and wellbeing of the individuals and the communities, addressing fuel poverty and social justice.
The final notes from the speakers were cautious optimism that the blended financing can assist developing countries, the data of the recent progress of the decarbonisation of grid across the world, climate activism of young people, who understand the importance of ending reliance on fossil fuels, technological capacity and readily available solutions to achieve Net Zero Carbon goals. Additionally, the importance of balanced planning of delivery to support the investment reducing carbon, not only focusing on upfront cost, promoting innovation that helps communities, not just the economically driven investors.

SESSION 5 - HOW MUCH DOES EMBODIED ENERGY REALLY MATTER?

Chair: Vanessa Gomes, University of Campinas, Brazil
Rapporteur: Magdalena Blazusiak, Robert Gordon University, Aberdeen

In the presentation titled 'The buried Giant: Construction materials shape the environmental footprint of buildings' **Rolf Fischnecht** asked whether net zero buildings are achievable, what are the effect of material selection on carbon footprint and what considerations are required to achieve the Net Zero goals. He talked about exponential growth and lifecycle analysis in the context of the history leading to the observation that while operational carbon decreases through the implementation of current and future standards, the embodied carbon of the development will typically increase.

This led to the summary of the Swiss guidance documents (KBOB 2009/1) regulating Life Cycle Assessment (LCA) and carbon metrics of the construction materials. The documents demonstrate evolution of the carbon footprint of construction materials across the years, with significant reduction of some of the structural materials and further predicted reduction of LCA in the future.

There are several Net Zero emission approaches – potentially avoided emissions, allocation, economic compensation, technical removal and use of biobased materials. Negative emissions technology can be achieved by multiple reuse of building elements or permanent sequestration.
In conclusion, the author summarised the importance of the building materials and their supply chains, relevance of embodied emissions, efforts to enable further reductions in carbon footprint of high energy intensive building materials and a requirement for negative emission technologies to reach net zero emission buildings. To support development of the built environment within the planetary boundaries, the required reduction in carbon footprint of buildings should be guided by legally binding target values, with reduction path to net zero by 2035.

The next speaker was **Simon Armstrong** from Drax with the presentation on the sustainable sourcing of biomass for energy generation. Drax have commissioned several experts who have reviewed the work of the company and provided recommendations on how Bioenergy with Carbon Capture and Storage (BECCS) can be successfully and sustainably implemented; Drax have accepted most of the recommendations and are reviewing operations to consider the implementation of the reminder. All operations are to deliver climate, people and nature positive outcomes. Biomass currently accounts for 12% of the UK's renewable electricity production.

The presenter expanded on the background and the role of biomass in the transition to Net Zero Carbon, the characteristics of biogenic carbon and carbon fluxes in forestry. The selection of feedstock for biomass and the framework considerations required to source sustainable biomass have been explained with the example of the British Columbia legal system requiring for the forest residue to be burned on site if no other use can be identified, which can be resolved with the use of such forestry residue for biomass production. The presentation was concluded on the regulations and audits of biomass sources and the multiple benefits of BECCS and the responsibly and sustainably sourced biomass.

Q1. from the audience was on deforestation definition, primary and virgin forests.
Simon Armstrong explained that regulations are in place for all wood products imported into EU having to avoid deforestation and degradation of forests, although these may not yet be best defined. There is no one solution across the world, although the primary forest is in most instances managed, to protect and maintain it.

Q2. concerned how realistic expectations are of the material producers and their aspirations to achieve carbon reductions and the Monte Verde Declaration that requires all products to be net zero by 2035.

Rolf Fischnecht suggested two decades may be required to implement changes in the construction materials sector, where available technology already exists, but highlighting the crucial requirement of the mindset change to enable progress.

Q3. referred to the biomass stack emissions and the potential risk of delayed warming.
Simon Armstrong responded that the use of the forest residuals in the biomass plant for energy generation displaces coal supporting the transition from fossil fuel in energy sector and enabling better management of forestry fires, where burning of the forestry residuals as required by law in BC releases carbon with no benefit of energy production.

Alice Moncaster gave a talk on 'Whole life carbon as a socio-political issue' that was based on several research papers around social and technical aspect of delivering sustainable development, the individual, industry and political decisions on environmental sustainability and the sustainability outcomes through the decision-making processes.

As part of the talk, the author described her study into school development in the UK in 2008, and the innovative decisions for alternative CLT structure based on embodied carbon calculations compared with steel and brick. The decisions for sustainable investment were dictated by the Government incentives, the Schools' Carbon Calculator allowing investors to secure additional funding. The tool however imposed the requirement of biomass boiler installations as the main source of heating, which was not always the most appropriate and sustainable solution.

This led to the question of further research on the transition to lower impact buildings and the introduction of LCA. The hypothesis looked at the 4 mechanisms: the role of individuals in the project, the tool and artefacts that are used in design, the industry and organisational context and the national policy and regulations landscape, assessed through qualitative case studies. The conclusion was that the individuals, artefacts and interactions steer the transition to the lower-impact building, with the designers being influenced by the guidance. Policymakers and planners can have a role in the decision-making process, concepts and artefacts can act as boundary objects and the guidance for people assist in sharing of their knowledge. This is also defined by the industry and organisational context of decision makers and investors for different building types along with the interactions with policy.

It has been suggested that implementation of LCA can be encouraged by the openness, transparency and knowledge sharing, development of open-source database and guidance, consideration of national context and project type.

The IEA EBC Annex 89 ST4 (2023-2027) is an ongoing research project which will assess the impact of structures and agents on the sustainability decisions and outcomes. It will entail a database of case studies, including different project types, procurement and construction approaches, regulation, country, organisations. This research will outline the importance of the decisions and the criteria of the choices in supporting lower-impact development.

Ambra Gulietti of Velux presented the experimental Living Places development in Copenhagen.
The presentation explored targets imposed by Velux on reduction in carbon footprint of their products, partnership with WWF and desire to show how to build sustainably inspiring the industry to find partners and promote innovation.

Velux demonstration buildings encourage learning from post occupancy evaluation and the investment in innovation. The Living Places initiative was focused on scalability, affordability and use of readily available construction methods and materials. It is a pilot of small sustainable, mixed use village development.

The shape of the building was determined by density of the development and the requirement for maximising natural light. The buildings were to provide healthy environments with abundance of shared spaces promoting sense of community, simplifying the buildings for adaptability, providing scalable solutions. The buildings were assessed by the third-party verifiers for

the environmental impact, reflecting the research into the indoor air quality, thermal comfort and carbon footprint as compared with standard single-family home of a similar construction.
Velux developed simple LCA comparison tool providing instantaneous visual representation of choices allowing to influence decisions based on the carbon footprint of used materials.
The question from the audience about the low energy house concerned wider industry involvement and potential for mainstream adoption of the solution in the Velux pilot. Velux have been engaging with the manufacturers to obtain EPD data for the LCA analysis, which proved to be difficult in some instances, especially to obtain accurate data for the services including ventilation. The aim was for transparency in the methodology of calculating accurate LCA's, however some assumptions had to be made where accurate data was not available.

Sue Roaf added a comment reflecting on the balanced approach to any development as exemplified here utilising passive strategies, allowing openable windows to assist in purge ventilation and supporting building resilience. The embodied carbon can be often used in the industry as a greenwash, looking at the modelling data, with promotion of lightweight construction, large expanses of fixed glazing, thus enforcing the use of energy reliant services in those buildings. The climate prediction data should be used for calculating comfort, with cooling requirement becoming a major focus, due to the accelerated global warming.

Vanessa Gomes added a remark of the LCA's being solely a calculation, not accounting for the passive measures and the importance of the whole life assessment in determination of best solutions and asked if the embodied energy is an issue and is perhaps perceived as an impediment to achieve Net Zero Carbon.

Alice Moncaster stressed the importance of the adaptation to future climates along with the mitigation of impacts on the future climates, where embodied energy is an issue. Rolf Fischnecht added that the balance of the embodied and operational carbon is essential.

Ambra Gulietti commented on local suitability and variations in construction methods in various climates.

Simon Armstrong commented on the complexity of the process and the meaning of sustainable development, inclusive of social and economic issues.

Ulrike Passe was concerned that the causes of the wildfires are associated with climate change and how the use of land in the future should have an impact on the choices of materials in the construction industry. LCA tools don't consider land use, including requirement of land for food production.

Simon Armstrong commented on the complexity of the calculating of carbon in soil, importance of moving from only accounting for supply emissions, to include socio-political aspects. Rolf Fischnecht concluded that LCA's for buildings can be scaled up to national accounting model including availability of resources at a national scale.

SESSION 6 - NET ZERO ENERGY STANDARDS AND ENERGY SUFFICIENCY

Chair: Alice Moncaster, University of the West of England
Rapporteur: Magdalena Blazusiak, Robert Gordon University, Aberdeen

David Partridge, Chair of the UK Net Zero Carbon Building Standard board discussed the principles of the standard supported by the main recognised built environment organisations. The standard is a collaborative, self-initiated, cross industry and purpose driven standard, that will provide an open and transparent set of metrics, carbon only and typology specific standard that will allow for environmentally conscious decisions with lower environmental impact. The standard is intended to regulate verification process and definition of Net Zero Building, can be used to support investment decision making and sustainable finance, that policymakers can incorporate into planning, procurement and leasing.

The standard is science based, prioritises energy efficiency, reuse, renewable energy and whole life carbon approach. It will be defined through top down workstream, which is a science-based approach, defining national carbon 'budgets' and building specific targets to achieve NZC goals and balancing the performance in the bottom up workstream, to create levels of performance and inform outputs.

The standard is not only driven by the professionals and technical teams, but through extensive stakeholder engagement directed at the whole industry to allow for adoption at scale.

Daniel Overbey of Browning Day and Ball State University, talked about the barriers and opportunities for greater thermal safety in the built environment through utilisation of Passive Survivability methodologies.

His presentation started with the description of the 2030 challenge lecture series at the University of Nevada that called for an immediate 50% reduction in energy use intensity of buildings in 2005, to achieve carbon neutrality by 2030. The current data reported by various sources indicates 50% reductions in carbon emissions in the built environment in and around 2021, which with the exponential increase of greenhouse gas emissions worldwide and implemented policies reported by IPCC demonstrate insufficient reduction in GHG emissions to stay within the 1.5° C warming.

This led to the description of the principles of passive survivability, that allow for design of resilient buildings that serve people and communities in the event of a weather emergency and unforeseen power outages. The definition of designing for passive survivability was identified as provision for public buildings and neighbourhoods to serve as a liveable refuge in the event of crisis or break down of energy, water and sewer system. The concerns over thermal stress have resulted in the institutional guidance for passive survivability.

Design for Sustainability and the Design for Resilience overlap, meeting the criteria for passive survivability, utilising natural resources and orientation of the site, supporting walkable communities and promoting net-zero energy, carbon and water buildings.

To successfully address passive survivability use of accurate climate projection data is required, together with recognising requirement for assessment of the Standard Effective Temperature (SET) and promotion of passive systems.

In order to model accurate performance of the building inclusive of the requirement for heating and cooling loads, accurate prediction data for future scenarios should be used. Publicly accessible climate data is essential, and the use of the database should be regulated and standardised.

In some circumstances passive cooling systems such as roof ponds have been described to provide effective cooling with no requirement for the energy demanding HVAC systems.

In summary, to successfully implement passive survivability there is a requirement for early-stage modelling tools allowing design team to optimise passive strategies. In addition, the climate projection data needs to be regularly updated and made publicly available, passive survivability metrics promoting passive measures must be utilised in early modelling of performance and tools developed for early comparison and optimisation of passive solar heating and cooling strategies.

Rahman Azari of Pennsylvania State University presented a paper titled 'Tackling embodied carbon: a gateway to Net Zero emission aspirations' addressing development of cities prone to climate change to resilient cities, developed within the planetary boundaries and taking cognisance of GHG emissions, energy, heat, health, equity and justice.

The growing population in cities worldwide requires developing risk estimation of hazard, exposure and vulnerability, that can be represented through metrics to enhance the understanding of the underlaying issues.

The trends of energy consumption in the US show that the energy demand has remained stable from 2007, unaffected by the increase of population and increase of the residential and

commercial stock, aided by increase of renewable energy production and effective implementation of the regulations.

Over 30% of the emissions are due to the operational energy, therefore the US Government Federal Sustainability Plan proposed to address the reduction in carbon emissions from the sector through energy efficiency measures, renewables and electrification utilising carbon neutral power.
US version of the Passivhaus standard has played a role in operational carbon reductions in Net Zero Energy buildings through implementation of the set of thresholds, addressing annual and peak heating and cooling demands.

To address the issue of embodied carbon, there are policies at local and national level, however there are no mandatory threshold regulating embodied carbon in the built environment. Natural materials, including the use of engineered timber can assist in reducing embodied carbon emissions, however, to meet the demand of the housebuilding industry the managed forestry resources would have to significantly increase, having implications on the land use and other potential unintended consequences.

Transformation of the assessment methodologies is required to support resilient development, considering interrelations between GHG emissions, air quality, water, heat, community; these should not be assessed in isolated manner. To move towards equitable and climate change resilient cities by 2050, energy targets and current energy demand should be monitored at national, local and sector level to inform decisions, using multicriteria assessment methodologies inclusive of health and social aspects of the environmental impacts of the built environment, develop and monitor benchmarks and pathways scenarios capturing climate uncertainty, develop framework assessing impacts of growth, equitable adaptation pathways, mandatory policy and successfully share the knowledge with the industry.

Timothee de Toldi presentation titled 'More is Good' was based on the research paper on the role of high thermal mass for climate change adaptation and mitigation strategies. It identified 3 main challenges: requirement for the built environment that lasts, emits less with the emphasis on the embodied emissions and cools passively in response to the climate change aggravated heat waves, which are a severe public health challenge in France and other countries.

Mechanical cooling can prove to be counter-productive, amplifying urban heat island effect and escalating contributions to climate change, socially unfair and unreliable.
High thermal mass buildings built with natural (non-transformed) geo-sourced materials were used in hot climates before the fossil fuels use intensified. Given the urgency of the climate emergency, industrial ecology roadmap requires the backing of policymakers for planification and quantitative analysis at the macro scale to ensure alignment with climate adaptation and mitigation targets.
The research questioned to what extent can passive cooling techniques meet the temperature demand for comfort and safety in current and future climates, at the national level. The passive cooling has been modelled as three-dimensional data to achieve method target temperature cooling for adaptive comfort and safety. Modelling compared cooling performance of high internal thermal mass building with nocturnal convective cooling, low internal thermal mass well-ventilated building and low internal mass poorly ventilated building. The results of the analysis demonstrated that cooling for comfort, temperature demand for safety and reduction in energy demand for colling can be best achieved in the first scenario of nocturnal convective cooling in high thermal mass building.

Ulrike Passe of Iowa State University discussed how free cooling from air movement can be a key to Net Zero and how to design naturally night convective buildings. Effective passive ventilation can be achieved understanding the nature of air flows: context including site, landscape and climate, flow paths and pressure differentials, creating the flow path through the building and courtyards as climate device, free flow open spaces and buoyancy and the wind eye modulating the openings and the flow path.

Prevailing wind patterns can present challenges however, night-time ventilation maps inclusive of future climate can be utilised to design successful passively ventilated buildings. It is important to recognise and understand the air flow and pressure differentials in the urban context. Urban trees and vegetation counterbalance the heat island effect and provide opportunities for provision of green urban corridors.

Creating the air flow through the building can be evaluated assessing the traditional building strategies, utilising cross ventilation, stack ventilation and chimneys as climate device. Natural ventilation can be successfully applied with the openable windows: the wind eye.
In the proposed new carbon metrics for natural ventilation, calculation is based on natural ventilation potential days with building energy fabric gains and losses.

Q1. related to the central metric of embodied and operational impact divided by the meter square of the building over the whole life of a building. The panel discussed how the importance lies in the comparability and understanding of the purpose of the data. Consensus is required of method of the calculation using the gross or heated area of the building, to present comparable data representative of the embodied carbon emissions of the development.
Ulrike Passe added that it is essential to change the way the buildings are built, reflecting on the construction techniques and the timeline of the development.
Timothee de Toldi added that the methodology will depend on whether the purpose is to reduce the intensity of emissions per square meter of construction or reduce the emissions in absolute term.

Q2. related to the progress made in the understanding and the methodologies currently used to address Net Zero Carbon.
David Partridge reflected that the standards and the drive to reach Net Zero is no longer technically and academically driven, as more stakeholder groups are actively engaging, thus becoming mainstream to assess new and existing asset.
The panel concluded that the methods of addressing climate emergency will be driven by the traditional methods, proven to work passively and that there's an understanding of economic benefit of Net Zero Carbon and decarbonised grid.

SESSION 7. GLOBAL INSIGHTS INTO NET ZERO

Chairs: Jesica Fernández-Agüera and Samuel Domínguez-Amarillo
Rapporteur: Tristan Sahwell, University of Idaho, USA

Presentations in this Session were from:

- Norhayati Mahyuddin on *Energy Efficient Retrofit Strategies towards nearly Zero Energy Kindergarten Building in Malaysia*
- Vanessa Gomes on *When means and ends meet: examining strategies and carbon accounting fit for Our Global Future*
- Rajan Rawal et al., presented by Susan Roaf on *An investigation of the operational energy and carbon savings from practicing adaptive thermal comfort theory.*

Achieving Net Emissions is now perceived to be a main strategy for ensuring a sustainable future on a global scale. This ambitious target has spurred a wave of innovation, policy shifts, and collaborative efforts across nations and industries. Building construction and operation are leading contributors to carbon emissions worldwide being the closest processes, and with the greatest direct involvement of society along with transportation. Efforts to radically reduce emissions range from retrofitting the existing stock to envisioning entirely new building forms and construction methods designed to minimise environmental impacts.

Norhayati Mahyuddin gave a paper on one such endeavor to achieve a nearly Zero Energy Building (nZEB) in a kindergarten in Malaysia which retaining the means to ensure comfort and

health for inhabitants. As the building sector operation constitutes a substantial share of the nation's energy consumption —most on commercial and residential spaces, the study advocated for widespread adoption of nZEB by 2040. However, it also acknowledged the unique challenges posed by Malaysia's highly demanding tropical climate, with a particularly high demand for energy-intensive cooling and dehumidification. The renovation and improvement of existing buildings is crucial, and the need for awareness and adoption of renewable energy technologies is emphasized. Passive strategies can provide a baseline — natural ventilation seems like main driver, but limitations in the architectural configuration, health risks associated with insects and the impact of the dense urban environment with airborne dust and pollutants restrains effectivity. Overall, the study highlighted the importance of specific and "actually" useful renovation strategies and policies to achieve energy efficiency goals in the construction sector in Malaysia, mostly linked with a greater penetration of renewables energies.

Vanessa Gomes highlighted another critical dimension in the race towards net-zero emissions involving comprehensive carbon accounting methods. These necessitate a meticulous examination of emissions not only from day-to-day operations but also throughout the entire life cycle of a building, including its supply chain. Strategies for carbon removal, including mineral carbonation and the use of biobased materials like wood, are gaining traction for their potential to mitigate emissions. She emphasized the challenge of achieving absolute zero greenhouse gas (GHG) emissions and highlights and the role of carbon offsets will play in the short- and medium-term. The text points out the lack of standardized rules and the need for harmonization in carbon offset solutions.

Furthermore, it is imperative to recognize that achieving net-zero goals is not a one-size-fits-all endeavor. Factors such as local climate and environmental conditions —as discussed formerly, available resources, and the specific type of building all influence the most effective approach. It is in these nuanced, context-specific decisions that the true challenge—and promise—of attaining net-zero emissions lies. This aspect is strengthened as in several regions, especially the poorer ones, may face greater challenges and limitations achieving net zero goals. There is a need for tailored approaches to carbon neutrality and the importance of global cooperation and resource allocation to achieve global decarbonization by 2050.

Rajan Rawal et al. use the case study of a pair of identical office modelled in the hot dry climate of Ahmadabad and the hot humid climate of Mumbai in India to show how important is the adoption of adaptive thermal comfort standards in buildings to provide a more human centered assessment of how to radically reduce emissions and energy use by promoting a more flexible and dynamic thermal environment employing natural ventilation and fans for cooling as well as air-conditioning when it is perceived to be needed.

Rawal et al. analyzed four scenarios for the same building in each climate in mixed mode operations incorporating natural ventilation, natural ventilation with ceiling fans, a mixed mode, and a fully air-conditioned mode as required to maintaining comfort conditions indoors. The combination of natural ventilation and ceiling fans, as well as a dynamic transition between mixed modes and fully air-conditioned modes, resulted in a significant extension of thermal comfort period while reducing energy consumption within this operational range. A crucial role was played by ceiling fans in optimizing the indoor environment, improving air circulation and facilitating heat transfer from the human body through convection and evaporation is discussed. The strategic integration of ceiling fans —vertical convective systems— in a mixed-mode approach enhances occupants' thermal satisfaction leading to substantial energy savings for tropical and mild climate areas.

All three presentations highlighted the need for designs that enable 'energy sufficiency', systems available in buildings that enable occupants to only use high energy heating and cooling systems when absolutely necessary to retain the comfort and health of users. This is an obvious way to effect

radical emissions reductions from buildings. Furthermore, the need to involve governments and global collaboration in such thinking to achieve ambitious zero-emission and energy efficiency goals was emphasized. These texts provide a wide ranging view of how zero-consumption strategies are currently being applied around the world.

Acknowledging that regions with fewer resources may face heightened challenges, to foster an honest and productive discussion about the global strategies to adopt. By harnessing the power of collective action, the global community has the potential to not only meet but exceed net-zero targets, ushering in a more sustainable future for generations to come while assuring citizens wellbeing.

WORKSHOP 1: BUILDING METRICS AND MODELS

Chair: Daniel Overbey, Ball State University, USA
Rapporteur: Magdalena Blazusiak, Robert Gordon University, Aberdeen

Workshop A1 focused on the building metrics and models aiding the data collection demonstrating and evaluating carbon reductions in the various areas of the built environment.

Christina Francis from London South Bank University presented a paper[1] describing *Carbon Accounting using Multi-Criteria Assessment (MCA).* The research objective was to define how the MCA multi-criteria tool for Smart Local Energy Systems (SLES) can evaluate carbon emissions, carbon reductions, carbon reduction potential of renewable energy and smart technology providing insight into socio-economic and environmental benefits. The tool can be used to assess project feasibility, utilising the user-friendly modelling framework integrated carbon accounting and lifecycle inventories.

The author's MCA tool consists of general calculations of a range of systems, environmental and socioeconomic variables and qualitative self-assessment regarding six themes: technical performance, governance, data management, people and living, business economic and environment. Self-assessment mapping clarifies progress towards the defined objectives in an easy-to-understand visual output.

Limitations in the development of the tool were related to the method of reporting on the carbon emissions for each type of energy generation where the greenhouse gas (GHG) emissions may have been overestimated, particularly in areas of high renewable energy resources. To overcome this and accurately estimate the impact of the non-thermal renewable generation, the authors suggest that the emissions are based on the installed capacity rather than energy production.

[1] Bjarnhedinn Gudlaugsson, Christina Francis, David Ingram, Camilla Thomson (2023). Carbon accounting using multi-criteria assessment for SLES: challenges and opportunities, University of Edinburgh, Scotland.

The use of the MCA tool had been tested using the ReCiPe method for lifecycle impact assessment (LCIA) and further demonstrated by the case study in Orkney, with existing and proposed development opportunities expanding the capacity of the renewable energy generation sources.

The tool facilitates a simplified, holistic assessment of the MCA of SLES and allows for consistency and comparison across the assessments in a user friendly MicrosoftExcel spreadsheet format. The limitations are based on the uncertainty of the source data. Further work is required to refine the carbon accounting process to ensure robustness and reliability of the outcome. The MCA tool allows for system wide impacts within predefined input parameters within system boundaries and mitigates issues of double counting. The research had been part of the wider Energy Rev project.

Mahsa Sayfikar from Heriot Watt University, Edinburgh presented findings from the study[2] on the *Variations of Energy Performance Certificates (EPC): Calculation Methodologies in European Countries.* The Energy Performance Certificates assist in establishing compliance policies and inform legislation by reporting Energy performance and Carbon Emissions of buildings.

The EU Energy Performance Building Directive has recently released revised requirement for the minimum energy performance standard for residential and non-residential buildings to align performance of EU member states in the drive to reduce net greenhouse gas emissions by at least 55% by 2023 and reach carbon neutrality by 2050. Research was conducted as part of a wider *CrossCert* project focused on comparing details of EPC methodologies and use the results to propose a harmonised approach for all EU member states.

The study found that some countries use EPCs based on calculation and others on operational energy rating. There is also a number of countries in the EU using dynamic simulations to assess non-residential buildings with complex HVAC systems or certain architectural features. Differences in software, energy categories used for the EPC calculation and methodology of the assessment were discussed.

It was found that most U-values of commonly used building enclosure materials are built into the software database, with some countries allowing inferring values to be used. The majority of countries require pressure tests to determine infiltration rates and used default temperature set points, profiles (occupancy, lighting and electrical appliances) and HVAC system parameters.

The conclusion of the paper was that methodologies may vary in the level of standardisation; however, most partner countries use a standardised approach for the calculation of EPCs. The next stage of the project will assess the requirements of the new EPCs taking into account requirements of the users and asset owners.

Hamza Hamida of the Technical University of Delft presented on the *Potential of the Solar Cooling Technologies and their Integration into the Building Façades*[3].Climate change and the associated temperature increase requires alternative approaches to cooling utilising renewable technologies and reduced reliance on fossil fuels.

Exposed building façades could be used for harnessing solar radiation and provide a renewable source of energy for cooling equipment in the warming climate. The author described various cooling technologies based on the energy conversion pathways. It was stated that firstly the need for cooling should be minimised through design and application of passive cooling measures, with application of integrated supplementary technologies as a secondary measure. The research

[2] Mahsa Sayfikar, David Jenkins(2023). Variations of input parameters in EPCs calculation methodologies across European countries, Heriot Watt University, Scotland.

[3] Hamza Hamida[I], Thaleia Konstantinou[I] , Alejandro Prieto[II] , and Ulrich Knaack[I] (2023) Solar cooling integrated façades: towards investigating product applicability, Technical University, Delft, Netherlands[I] and School of Architecture, Diego Portales University, Santiago, Chile [II]

paper provided definitions of the solar active façade and solar cooling integrated façade and highlighted challenges in the selection of appropriate technology tackling technical and product-related aspects.

The author's research methodology included the determination of quantifiable key factors of products and the criteria affecting technological selection in multifunctional façade application. Product applicability had been reviewed and discussed to enable a holistic selection of the product and technology using predefined criteria divided into three sections: technical and product related aspects, processes and stakeholder related aspects and financial aspects. Emphasis on the context and boundary conditions in design and development of the façade had been highlighted as one of the primary selection factors.

Q1. Asked about exploration to date of thermally driven technologies, lowtech and passive cooling technologies, such as stack effect and how they may be integrated into such a study. The research presented was yet to explore these applications and recognises certain limitations of applications integrated into the façades.

Oz Kira of Ben-Gurion University of the Negev, Israel gave the last presentation of the session highlighting the drive for the city carbon neutrality and the role of urban green infrastructure to achieve emission reductions through Remote sensing-based frameworks to quantify city-level carbon fluxes in urban green infrastructures[4].

The role of the green infrastructure in cities is well understood in mitigating urban heat island effect and improving thermal comfort, reduce air pollution, sequester CO_2 and provide centre for recreational activities. The quality of green infrastructure can be affected by the factors such as plant and soil type, management, topography, climate and weather and urban planning.

The research identified gaps in the knowledge of the balance between single green element to the whole-city green infrastructure and the carbon sequestration data limited by local measurements and city level estimations. The purpose of the research was to develop a remote sensing platform estimating net CO_2 fluxes of urban vegetation at a high spatial resolution in whole-city approach.

Remote approach of estimating CO_2 balance can be observed by the carbon sequestered by the plant in quantifying chlorophyl concentration to determine Gross Primary Productivity of the plant using satellite observation and incoming radiation data and accounting for the Ecosystem Respiration (carbon emissions from plant and soil) to calculate carbon net flux – Net Ecosystem Production, representing the sequestration capacity of green infrastructure. The research is conducted on local models and local field measurements using remote observations to generate high resolution CO_2 sequestration maps. The important aspects affecting the outcome are the resolution of the satellite images and the shade modelling.

The future aspirations of the study include a year-round model based on the local measurement, improvement of the vegetation classification and aid in decision-making to promote efficiency for better, resilient green city infrastructure.

Q1. concerned the potential use of the remote sensing to aid urban farming and relevance of satellite remote sensing for vertical growing and decentralised solution of green walls.

Q2. Was on the role of the sequestration potential of managed urban vegetation.

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[4] Oz Kira[I,II], Alexander Takele Muleta[I] , Julius Bamah[I] , and Shirley Bushner[I] (2023) Remote sensing-based frameworks to quantify city-level carbon fluxes in urban green infrastructures, The Civil and Environmental Department, Faculty of Engineering Sciences[I] and The School for Sustainability and Climate Change[II], Ben-Gurion University of the Negev, Beer Sheba, Israel.

A Roundtable Discussion on the potential of using vegetation to reduce carbon emissions within the EPC data, requirement for creation of better green urban infrastructure and the opportunities for the development of software aiding the design of resilient green urban spaces ended the workshop. The discussion summarised the importance of the interaction with the various stakeholders including the end user, to tailor the tools and research outcomes at the early stages of the study and touched on the potential of the SLES in the decentralised energy system within the smart grids, understanding customer and community requirements. It had been suggested that standardisations of climate projection models could assist in the development of the tools and technologies recognising potential limitations of current technologies to meet the future demand. The discussion was concluded with the importance of defining human comfort as physiological and psychological perception to assist in understanding of the concept of adaptability and formulating benchmarks supporting climate projection models and cooling demands.

Workshop 2: Behaviours and Decision Support

Chair: Robyn Pender, Historic Buildings Expert
Rapporteur : Mina Jowkar, Napier University, Edinburgh

Background

As the world confronts the pressing challenges of climate change and environmental sustainability, the spotlight is increasingly focused on the critical role of behaviours and decision support systems in driving the transition towards net-zero operation in buildings. While technological advancements have enabled significant strides in energy efficiency and renewable energy integration, the success of achieving net-zero goals centres as much on human actions and choices as it does on innovative solutions. Recognizing that buildings are not static objects, but dynamic environments shaped by occupants' behaviours and stakeholders' decisions, this discussion highlights the critical importance of understanding and influencing these dynamics. It is also crucial to explore the complex interaction between human behaviour and decision support systems and examines how they collectively drive the move towards net-zero operations in buildings, and why this link is fundamental to our sustainable future.

Ulrike Passe, for Fatemeh Yazdandoust from Iowa State University, USA started the workshop with a presentation entitled *Can we shape occupants' actions towards non-wasteful energy behaviour?* This presentation investigated a comprehensive framework that integrates passive strategies useful in optimizing urban form and building performance in densely populated areas. The presenter discussed suitable approaches for incorporating daylighting and natural ventilation at two scales of building and urban, achieved by examining existing passive form-finding strategies and integrating relevant previous studies.

Xiaonan Li and Qingchang He from University of Pecs, Hungary and Shandong Normal University, Peoples Republic of China, respectively followed this with a presentation on *Green roof and PV panels of public buildings for energy savings and to alleviate climate change.* They focused on the application of greening interventions covered in the Hungarian context can be quantified using a carbon-neutral and inhabitant-friendly tool. The presenter discussed how these technologies are contributing to the adaptive regeneration of the city, and how it points a way towards a turning point for the future development of the city.

Q1. Have you considered the combined impact of the green façade not only on the building, but also on the environment? The presenter confirmed that they simulated the influence of the green façade on the building and the surrounding environment and wildlife. They also

mentioned that the green façade had a considerable impact on the thermal comfort on the area around the building.

Luke Gooding and Sonja Oliveira of the University of Strathclyde, Glasgow presented the findings of a study entitled *Visualising carbon in the design and delivery of buildings – A review of the evidence*. They provided a comprehensive review of related studies that visualise practices relevant to carbon reduction in the design and delivery of buildings. This was really interesting. The researchers had started by asking the question on *how does the way you visualise/present data in this field affect your analysis?* Of particular relevance and interest is the discovery that, asked to visualise a 'good' future, M&E engineers all drew outdoors, open windows, no controls – and expressed that their own ideal building wouldn't have space conditioning. When asked why they then added controls, they answered that it was: that's what people expect from the professional! Also: Drawings and plans almost never incorporate people, and in the rare cases they do, are stylised and men – there for scale only.

Koran Kandilci and Duygu Aral from Izmir Metropolitan Municipality, Turkey brought a presentation entitled *Towards a City Sustainability Hub: Advancing Urban Sustainability Governance Through a Participatory Approach* written by Ebru Kandilci Köran, Duygu Aral, Can Tunçok, Koray Velibeyoğlu. The presenters discussed the collective conceptual development process of a sustainable hub in Izmir, Turkey called "Izmir Sustainability Hub". They investigated this hub as a case study and introduced a framework for sustainability hubs in Turkey.
Q1. How did you arrange the workshops?
Q2. What was the gender distribution among participants or those interested in the workshops? *This question led to an open discussion on the topic, and the was a consensus that females typically show more interest and engagement in such activities and topics!*

Closing Discussion
Since the group was small, we decided that an open discussion was more useful than conventional question-and answer. And so it proved!
The central topic was the deep dichotomy in current climate narratives, actions, research, even in the way carbon is visualised:

- Although legislation and public discussion all focus on the fabric of the building, in fact the consumption of energy in the built environment is about the users; and yet there is little if any discussion into people are using so much energy in the first place. The current narrative assumes:
- That usability requires the input of energy, notably in the form of space heating and cooling
- That therefore engineered solutions are required
- That "behaviour change" must be the framework for any discussion around reducing energy
- But in fact:
- Despite all the action and expenditure of resources, energy consumption in the UK is still rising
- The real problems – and real solutions - are more subtle, and require a different less siloed approach.
- It's 'built environment', not just buildings
- There is still too little recognition of the fact that the future climate will be different – probably hotter, especially in cities.
- The whole question of energy and carbon in buildings is better framed as 'people first', or 'building usability' first.

- There is a risk from using energy narratives to cut carbon, and vice-versa: you need to think holistically.
- We have a long history of building construction and use that predates space heating and cooling; and indeed is ongoing in the Global South; we need to learn from that.
- There is a serious gender disparity here – women are more likely to think of non-engineered solutions, but they have less decision-making power.
- There is the problem of 'solutions' being marketeered – for example, 'Insulate Britain'.
- A huge issue (certainly for carbon, but also for effective action around climate, carbon, energy built environment…) is that of longevity and maintenance. That needs to be a central part of the carbon accounting, and not just for materials, but for assemblies, for buildings in use…
- How do we get to 'good enough' assessment? Good enough to feel confident that we are on the right pathway to success…

KEY MESSAGES – also repeated in the Legacy Document

Going from this Workshop discussion into Sessions 4 and 5 was very interesting. There were all men speaking, and though they all gave great lectures, there was little or no questioning (explicit or implicit) of the engineering-first market-led narratives, not even from Jonathan Porritt (who spoke approvingly about 'Insulate Britain', without realising that it was clearly corporate capture). And therefore no discussion of that central point: W*hy* are we using all this energy in the first place? Where it is truly useful, and where is it just poor habits. Where were the thermal physiologists were showing how much healthier people are if their thermal environment is NOT tightly controlled, as they did at Sue Roaf's Climate at the Extremes conference on Covid, Comfort and Ventilation last year (www.comfortattheextremes.com).

What can we learn from the long history of the built environment, in the way that it was operated as well as constructed, especially before and after the introduction of fossil fuel combustion? What has changed, and why? There is so much to be learnt and understood from looking at that history, and it has every potential to make dramatic cuts quickly and without risk.

So, the big question is: how do we derail the current juggernaut to doom? It will require

- New messaging – based not least on a deep critique of current messaging
- Empowering people to be able to learn to 'sail their own buildings'
- Engage the professions in a new way – getting them to question/ drop methodologies they don't even LIKE, but continue to use simply because they think everyone else is doing it…
- Look at the whole timeline – from past right into the future, including understanding change and failure – accepting once again that decay (and the need for maintenance) are baked in for ALL materials.
- Start insisting on knowledge of 'failure modes' to be prerequisite before a material or assembly is used.

WORKSHOP 3: WHOLE LIFE AND EMBODIED CARBON ACCOUNTING

Chair: Rahman Azari, Pennsylvania State University, USA
Rapporteur: Shristi Tamrakar, University of Idaho, USA

Paola Seminara (writing with Andrew Livingston, and Julio Bros Williamson from the University of Edinburgh) opened the workshop with a presentation on *a Carbon Evaluation and Hygrothermal Performance Comparisons of Stone Wall Retrofits*. This presentation dealt with the subject of natural and recent man-made insulation material in stone wall retrofits, and the impacts of considering both their hygrothermal performance and an evaluation of the carbon embedded in the material. 80 % of timber used in the UK is imported and 22% is used in the construction industry. The emission footprint of import and transportation of the timber industry accounts for 83 % of the total emissions, of which 49% is from imports and 34% is from transportation. He also mentioned that new buildings have lesser average space heating demands than the existing buildings even though the demands are decreasing in both cases.

For the study, they accounted for both embodied carbon as well as operational carbon. Considering different types of Scottish dwellings, they analyzed the 3 applications: application of natural insulation 100% softwood (100SW), mix of 80% softwood and 20% hardwood (80SW_20HW), and high-performance synthetic insulation (PIR). Two scenarios were evaluated involving a minor retrofit (MiR), with a U-value of 0.50 W/m^2K, and a major retrofit (MaR) with a U-value of 0.22 W/m^2K. Adopting 80SW_20HW vs 100SW resulted in a 16% reduction in insulation layer thickness in the pre-1919 existing wall. Additionally, the condensation risk analyses of the upgraded wall were done. There was 57% higher moisture accumulation on 100SW on the cold side of the insulation.

In conclusion, the use of an 80-20 ratio of softwood and hardwood resulted in thickness reduction, lesser condensation risks, and the use of different resources than using 100% softwood. Natural-based insulation products made in the UK with local material can reduce emissions associated with the timber industry including up to 80% transport-associated carbon emissions.

Q1. Asked about the use of hardwood for insulation. It was proposed that it has better performance for insulation than many other products and lots of cut off and scraps could be used for hardwood insulation.

Q2. Questioned whether hardwood has less carbon stored than softwood.

Q3. Asked whether wood insulation has a higher thickness than PIR and how would that would work in a commercial setting. This required financial, natural resources, and carbon emission optimization.

Rosemary Fieldson and Ozlem Duran of the University of Lincoln made a presentation on the *Impact of Location Selection on A Whole Life Carbon of a Multi-National Manufacturing Facility* by followed. They introduced global manufacturing as characterized by energy use of high scope 1 and 2, and spoke of the need to offset scope 3 emissions. The amount of carbon emitted will differ around the world depending on where manufacturing is located. They chose a baseline project LCA as a manufacturing facility opened recently in the UK. They calculated material impact A1- A5 and analyzed design life sensitivity. While buildings have an assumed life of 60 years, most of the structures are likely to be torn down in 25 years creating significant building services replacement impacts. For better impact distribution, alternative locations should be considered, according to the presenters. For this, a country's energy mix needs to be adjusted, energy demand needs to be reviewed, and local Environmental Product Declarations (EPD) need to be adjusted and reframed.

They questioned the Whole Life Carbon metrics on various measures such as using GIA when considering the walkable service voids/ceilings push the building above UK targets for embodied impact rate and longer reference period considered than true design life.

Recommendations for end users included prioritizing savings in manufacturing processes, utilizing parametric models and digital twins to model embodied emissions, assessing end-of-life decisions, and focusing on the frequency of replacing services. Scoping pros and cons for local decarbonization, modeling operational energy targets and design life with the local grid, refining

modeling with materials for the envelope, and engaging suppliers and contractors in the EPD and fuel consumption conversation should be done. UK construction industries should improve the LCA procurement approach and geographical supply chain mapping.
Q1. asked if the importance of the choice of location was due to the cost of transportation, which is also associated with the cost of social costs and carbon costs.
Q2. asked what should be preferred cradle to grave, or cradle to grave under one click LCA? The presenter answered both are the targets for procurement and should be analyzed before choosing one.

Bofa Udisi, Fatma Osman, Mark Gorgolewski et al., of the Toronto Metropolitan University presented a study on *Quantifying the Embodied Emissions of Building Envelope Systems in A Toronto Context* by followed. Bofa Udisi described the Canadian context of how emissions reduction were implemented with more stringent building codes and standards around energy efficiency in buildings. There are relatively clean electricity grids and reduced operational emissions due to fuel switching. As our buildings become more energy efficient, studies have shown that the embodied carbon will represent a higher percentage of the building's whole-life carbon – up to 80% they suggested. The current Canadian Landscape showed targets on embodied carbon through the Toronto Green Standard, Vancouver Building Laws, and the Canadian Green Building Council. In their initial research, they found a gap where enclosure systems did not include a roof and floor. This prevented us from understanding the embodied impacts of enclosure layers and easily selecting the most sustainable materials and systems early in the design process. The objectives were to develop a replicable methodology for enclosure assemblies and then quantify the embodied carbon of 26 commonly used enclosure assemblies of Part 3 buildings in the Greater Toronto and Hamilton Area. The assemblies needed to be among the commonly used in the GTHA and the selections had a variety of materials. It was also important that they could be used in new construction and some for retrofit applications. After the evaluation, 26 assemblies were shortlisted. 17 of them were wall assemblies and five roof and four floor assemblies were selected.

The results showed assemblies built with wood-based structures perform better than concrete, brick, and steel. The worst-performing were concrete backup structures. Procurement professionals can use the guidance document to quickly compare the impact of specified designs. On the policy side, the results can be used to define carbon budgets for building enclosures in new construction and retrofit scenarios.

Q1. Are such goals realistic? Udisi answered that the goals were ambitious and aimed high. Fuel switching from natural gas to electricity encourages electrifying everything. This results in heavy demand and natural gas might be required again.

Q2. focused on the benefits of having a fixed R-value and U-value for all materials, and material thickness would then be dictated by the required R and U-values to be achieved for that material.

Joe Sanchez, Bamdod Ayati, Harry Sumner et al., University of East London presented a paper on *Embodied Carbon Performance Gaps in Timber Production.* The study had been done as a collaboration between the University of East London and Haptic, a public/private sector project together with a shared interest in understanding the true impacts of forestry practices. Relationships with timber as a construction material pre-date recorded history in forms of mass timber and solid log construction using locally sourced timber often rolled, dragged, or carried by horse and cart. Frames were developed, with trusses and crucks for buildings. In the modern-day context, timber is used widely as a construction material both internally and externally. Haptic in research partnership with the University of East London designed King's Cross W3, a community building. The hybrid frame supported the timber façade and vertical and horizontal elements. The building outperformed aspirational targets from the Greater London Authority. With this and other examples of timber structures, the opportunity to reduce life cycle embodied emissions through mass timber has been recognized. However, there are uncertainties and complexities involved in the environmental assessment of timber production and what happens with greater demand.

The research questioned any gaps in the Life cycle assessment of timber products in the UK, where they form, and what it meant for practitioners. The presenters concluded that, first, dynamic LCA can introduce the temporal aspect of carbon footprint calculations. Second, trees have global warming potential during their growth till 30 years. Third, peat oxidation and albedo change can be modelled through dynamic modelling. They recommend using fast-growing materials such as common reeds. Bagasse the by-product of sugarcane has been shown to offer strong structural and insulating properties. They can be harvested multiple times per year and can solve agricultural issues such as re-wetting the land and supporting productivity.

Q1. How is it best to explain and teach low-carbon timber architecture to students? A new approach should be adopted reframing the courses to include the life cycle of buildings. Buildings should be treated as a process rather than a thing, then carbon education can be added.

Q2. Queried the source for the sugarcane blocks as byproducts to be used in materials from Vietnam.

Q3. The final discussion addressed the question of when the timber has been so well appraised as low carbon and everyone tries to build out of it, what happens in areas where there is not enough timber?

Bruce Haglund, Tristan Sahwell, and Shristi Tamrakar of the University of Idaho presented a *Case Study of A Low-Carbon, Mass Timber Arena* was presented by Tristan Sahwell and Shristi Tamrakar presented a study of the embodied carbon and the life cycle analysis of the ICCU Arena situated at the University of Idaho, USA. They talked about the 2022 U.S. Inflation Reduction Act showed the importance of low-carbon building materials due to the growing focus on reducing embodied carbon. They introduced the ICCU Arena, which opened in October 2021 and talked about its design and structural features. Several glulam beams stretched to cover the 67,000 SF structure. The timber came from the university's experimental forest, 10 miles from campus. The Idaho Department of Ecology and Natural Resources was heavily involved. However, their goal did not include sequestering carbon or reducing carbon footprint. The local wood had to travel to Boise, Stanley, and Abbotsford, British Columbia for fabrication, which added embodied carbon. Local fabrication would have been better.

They showed their comparison study with Swiss Arena in Zurich and Doran's Towards Half: Climate Positive Design studio. The ICCU Arena's embodied carbon, with its concrete substructure, was 213 kg of CO2 per square meter, which was slightly less than Doran's studies of low-rise wood frame buildings with concrete foundations. The Athena LCA showed concrete as the most carbon-intensive, which accounted for 87% of the total embodied carbon of the Arena. Though the arena

was not net-zero, it was low carbon and could have used better materials. They talked about Amin Taha's idea of post-tensioned stone beams and foundations and Drabkin and Mead's carbon sequestering admixture concrete for carbon negative slab. Overall, the ICCU arena points toward a lower carbon future.

Q1. What about the more recent comparable materials?

Q2. Will bio-admixture concrete/ materials would have enough strength as timber equivalents?

Q3. How would such materials weather when used in a building?

Q4. Would the concrete in the foundation have been lessened if the structure was steel rather than CLT. Mass timber buildings are generally lighter than steel and concrete framing, thus require less massive foundations. With steel, they would require even denser concrete and would have increased carbon even more. They also added that there were facilities and usable spaces underground which accounted for the concrete.

WORKSHOP 4: NET ZERO COMMUNITIES

Chair: Andrew Peacock, Heriot Watt University
Rapporteur: Adam Henderson, University of Edinburgh

Workshop 4 focused on Net Zero at the community level. As our current grid systems undergo a seismic shift as renewable technologies enable energy decentralisation, there is a heightened role of communities in the new energy system, whether it is in generating their own electricity, or being in close proximity to new infrastructure projects. Whatever the future brings, it is clear that communities will play an important role in the international drive towards net zero.

Laura Moldovan from the University of Strathclyde presented a small fragment of her wider PhD research, focussing on *the socio-spatial impacts of energy storage.*[5] Energy storage technologies are a critical aspect of net zero targets and meeting decarbonisation policies. In the near future, the number of battery energy storage systems (BESS) will increase rapidly. In the UK alone, 408 community-scale BESS are currently in or awaiting construction, and the country boasts the largest battery storage system in Europe. With this context of increasing BESS deployment, Laura noted a lack of attention given to its impact on people, community, and the spaces nearby. While there are studies which show that energy infrastructures do have significant implications on people's social relations, energy practices, wellbeing, and health, these are poorly defined within the context of energy storage infrastructure.

The literature review brought together work focusing on the socio-spatial impacts of energy infrastructures. These studies were then grouped under the key themes of *place making*, and *sense and meaning making*. Within these broad themes, new energy infrastructure can have negative impacts on people's lifestyles, attitudes, identity, and can also affect place attachment and identity. Both socio and spatial impacts have been studied using a variety of theoretical frameworks, including Science and Technology Studies (STS), Social Construction Studies, and Social Acceptance Studies. Each of these frameworks present benefits and limitations, and though no one framework is able to provide a full insight into infrastructure impacts, each has certain benefits which can be applied to BESS and help researchers better understand the full implications.

[5] Laura Moldovan, Sonja Oliveira and Ombretta Romice (2023) Accounting for socio-spatial impacts of energy storage technologies – Learning from energy infrastructures literature, University of Strathclyde, Faculty of Engineering, Department of Architecture, Glasgow, UK

This work highlighted the importance of how energy infrastructure impacts relate to the end user, whether that is the individual or whole communities. The work also provides a novel insight for policy makers, practitioners, and academics on the socio-spatial impacts of energy storage infrastructures at a range of scales.

Iain Struthers from the University of Edinburgh then presented a small section of his wider PhD research. The work focused on how *communities can become zero carbon through co-location of marine renewable energy*[6]. Beginning at a macro scale, Iain explained how the carbon intensity of electrical power consumption of communities and households is dependent on power flows from national transmission and local distribution networks. Therefore, for zero carbon communities, the injected electrical power must have a carbon intensity of zero (0 gCO2/kWh). The problem is that due to constraints on the GB transmissions network, remote communities may not be able to achieve time-bound, zero carbon targets. However, there are some remote parts of the GB grid which are close to regions of the UK with high marine energy resource, notably in the North-East and South-West. The work presented explores the emissions reduction potential of marine renewable generation when co-located with these remote communities.

The analysis was based on the National Grid's Future Energy Scenarios (FES), though the energy models had to be modified since the FES has minimal levels of installed marine capacity. The power flows were modelled in a node network model using the power system modelling tool PyPSA-GB. By comparing the FES against scenarios with higher installed capacities of marine energy, it was shown that marine energy can further reduce emissions for remote zero-carbon communities. Interestingly, this was true at the national scale, though not necessarily at the local scale at certain nodes. At the local level, the carbon intensity did reduce in the North-West. However, in the South-East, carbon intensity increased. This was likely due to carbon accounting assumptions, but this requires further exploration as the work is still in progress.

The final presentation of the session was delivered by Sue Roaf on behalf of **Matthias Haas from Zurich University of Applied Sciences, Switzerland.** His paper demonstrated how renewable energy can be supplied in existing buildings, in particular, how *solar PV can contribute to circular principles*.[7] In his scenario there are three main contributions; PVs enable distributed energy production, self-sufficient sources of energy for whole regions, and sustainable, decentralised energy production which ensures supply in the long-term. Increasingly, there is a transition towards a system where the individual has a greater role in energy supply chains as a prosumer, where consumption and production of energy occurs simultaneously. The reliance on the grid network can be grouped into three levels of self-sufficiency, which forms the basis for this work's analysis. Firstly, tendential self-sufficiency where there is a partial reliance on the grid, soft self-sufficiency where the majority of energy demand is met with self-production, and hard self-sufficiency, where there is no reliance on the grid network.

Using these definitions and three case studies (base case, with consumers, with consumers and storage, and consumers and storage with a three times larger PV system), a simulation was run to assess a range of performance and economic factors. The main results show that the level of self-sufficiency increases with PV size and when storage is included, though in the case of a larger system, 50% of the energy was exported. In terms of economics, all cases were profitable, though the third case was significantly more so. These results indicate that in terms of optimizing residential

[6] Iain A. Struthers, Andrew Lyden, Wei Sun and R. Camilla Thomson (2023) Achieving zero carbon communities by colocation of marine renewable energy, University of Edinburgh, Edinburgh, Scotland, UK.

[7] Matthias Haase (2023) How circular is a renewable energy supply of existing buildings?, Zurich University of Applied Sciences, Switzerland

PV, the system dimensions should not be based on self-consumption, but on the maximum size of system that can be achieved.

Discussion: This Workshop ended with a spirited roundtable discussion, beginning with questions arising from the first presentation. The group discussed how new infrastructure, BESS in particular, could be disguised to reduce the negative impacts on the surrounding area. The risk of fire and general safety concerns were brought up, and how educating and informing the surrounding inhabitants could allay some of their worries and fears about the new BESS. Finally, the merits of fiscal reimbursement for locals was discussed, and whether this would be a useful strategy in getting locals "onside". The rest of the discussion covered topics raised in all three presentations, the ability of new energy infrastructure to "unlock" new benefits for communities. In some parts of the UK, where communities are at the end of the grid, they are currently unable to make the most of technologies such as EVs since the grid connection is too poor and unreliable. However, with the addition of BESS, marine energy in isolated communities, and residential PV, these problems will be ameliorated, and hence new opportunities are unlocked. This was but one example of how the emergence of renewables can transform communities worldwide.

WORKSHOP A5: NET ZERO UNIVERSITY CAMPUSES

Chairs: Alex MaClaren, Heriot Watt University, Keith Baker, Glasgow Caledonian University
Rapporter: Akashdeed Dey, University of Edinburgh

Introduction:
The global push for sustainability and carbon neutrality has prompted universities to undertake innovative and tailored approaches to address their environmental impact. Four distinct presentations, based on experiences at prominent US and EU universities, illustrated the diverse strategies being implemented to lower carbon emissions and promote sustainable practices within their campuses. These studies four not only underscored the critical role of universities in driving meaningful change but also highlighted the challenges and opportunities unique to their respective contexts, locations and roles within cities. From leveraging voluntary carbon markets to imposing sustainability requirements on suppliers, the projects showcased the multifaceted nature of achieving sustainability goals in the face of political, structural, and operational complexities. They emphasise the importance of data-driven decision-making, comprehensive planning, and collaborative efforts in fostering a culture of sustainability within and beyond the academic community.

The session heard from researchers at three European and one US university, each grappling with developing actionable and effective net zero strategies to meet the climate emergency. Each presenter made clear the essential relevance of local context, in terms of the buildings involved on their campuses, stakeholders in them, local climates and energy infra-structures. The sessions covered various aspects of the Net Zero challenge; finance, governance, simulation and strategic planning, with many issues common to multiple studies while others we unique to their own context.

Robert Koester of Ball State University (BSU), Indiana in the USA has a well-established long-running process of decarbonisation, which has been benchmarked and applied to create carbon credits that will ultimately finance further carbon projects. Since 2011, the University has worked collaboratively with the Climate Neutral Business Network (CNBN) in piloting the application of a methodology to develop a Campus Clean Energy & Energy Efficiency (CCEE) based on greenhouse gas emissions reductions that are qualified for transaction in the Voluntary Carbon Market (VCM).

Over the last twelve years, BSU has been able to garner significant Carbon Capital for use in expanding its CCEE efforts, to become a Climate Neutral Campus by 2030.

The presentation focused on leveraging a voluntary carbon market, to further invest in deeper carbon reduction projects. This was presented in detail, with comments on the context in which the USA significantly relies on a fossil fuel economy. The speaker explained that the first approach was to prepare the university's Verified Carbon Standard (VCS) project application, including the estimated short and long-term emissions reductions. It then generated the Sustainability Indicator Management and Analysis Platform (SIMAP) to determine the campus-wide greenhouse gas reductions as reported to Second Nature (SN)and the secretariat for the nationwide Climate Leadership Commitment (CLC). This is followed by an annual verification process including internal tracking and quality assurance of the reported metrics. As a result, this scheme then used third-party sign-off on VCS project verification reports and the SN management of this work under the rubric of the Carbon Credit Purchasing Program (CCPP) by which it brokers credit registrations and transaction procedures in the VCM. The presentation concluded with a review of the emerging social cost of carbon, a metric now used by institutions to shape their emission reduction strategies.
Q1. was about the obligations that are set for carbon neutrality and the ultimate target for the university. There were also questions about the primary use of buildings in the campus, which resulted in mainly teaching and some research laboratories. A discussion continued on the impacts of regional and national politics on the university's carbon neutrality policies, where the speaker interestingly told the audience that despite being a publicly funded university in a coal-producing state, Ball State University has been able to stop burning coal and thus, has been able to avoid 65000 metric tonnes of carbon emissions. However, there are political aspects at the institutional, local, and national levels, which can sometimes hinder policies towards the university's carbon neutrality.

Deirdre van Gameren of Delft University of Technology (TU Delft) in the Netherlands presented a strategic framework for measuring, auditing and reducing carbon emissions across their campus. This was driven by a strong commitment from university leadership and a cascading hierarchy of sustainability-focussed positions throughout the institution. The sustainability leadership team aimed to render themselves irrelevant by building sustainability audits and metrics into each standard role at every level. A compelling snapshot of an organisational commitment to rapid change led from the top but delegated through all levels. The presentation delved into a vision, ambition and action plan with 5 specific goals adopted by the university's executive board. The ambition is that by 2030 the university wants all activities on and from the campus to be carbon neutral, circular and climate adaptive, contributing to the quality of life for its users and nature, and demonstrating sustainable innovations on campus. This paper will show which steps TU Delft has taken to set these ambitions in place and how they want to become a climate-conscious University and example for others. The main elements addressed are Sustainable Operations and Behavioural Change.
Q1. was about how product suppliers to the university responded to the requirements of carbon footprint reporting. To analyse this, two PhD students worked extensively on assessing the carbon footprints of supply chains and as a result, new suppliers are required to assess and report their carbon footprint in tenders, which suppliers are now getting used to doing. The university, for example, assesses the carbon footprint of its catering precisely, and the speaker insisted that all universities and companies should apply this requirement.

Sara Dorregaray-Oyaregui of the University of Navarra, Spain is located across three campuses with very different teaching portfolios and student cohorts at each location, as well as different built environment contexts. The purpose of this study was to gather valuable information that will aid in advancing the sustainability strategy of the campus. The study focuses on the key findings of the carbon equivalent emitted measurements of three university campuses located in Pamplona, San Sebastián, and Madrid. The project comprises 17 different initiatives under 7 areas where carbon

footprint, is used as an indicator of the environmental impact of its activities. This essential data enables decision-making, prioritisation of current projects, and assessment and planning for future projects.

During the 2021-2022 term the university emitted a total of 10,812 Tons of CO2 eq. mainly for space heating using natural gas boilers, university-owned vehicles, air conditioning systems, electricity consumption, seasonal student movements (domestic and international), and employee trips and stays for work-related purposes. The work presented was focused on one of these locations and developing strategies for reducing carbon emissions through building simulation modelling with accurate systems and occupancy detail. The presentation provided insight into stakeholder engagement and the levels of complexity reflected in the simulations. The work is ongoing.

The speaker was asked how the impacts of climate change are accounted for in the university's models for carbon neutrality; like the requirement for less heating (perhaps) with increased global warming. The speaker responded that since most buildings are at least 50 years old, the scenario is already complicated. Modelling the changes required for buildings will take time.

Julio Bros Williamson of the University of Edinburgh gave a talk focused on the Building Estates departments across the country that struggle to find an efficient and cost-effective way to meet net-zero targets of reduced operational and embodied carbon emissions. Often in dispute are the methods and the speed of delivery of any solution that reduces energy demand and carbon emissions associated with the building, particularly those requiring upgrading and retrofit. On one hand, there are electrical heating systems (heat-pumps) that substitute gas heating technology (gas boilers), and on the other, there are specific building envelope performance retrofit interventions that reduce energy demand but need to be archetype-specific and may take longer and impact occupants. Although the speed of carbon reduction and the initial upfront costs are deciding points to consider, other options need to be analysed, such as the whole-life carbon of solutions, maintenance, replacement costs and the thermal comfort of users over the occupation periods. This presentation discussed the two methods outlining the social and economic impacts and an approach that considers a whole-life carbon balance that is relevant to the retrofit of non-domestic buildings in a university campus setting.

The University of Edinburgh presides over a hugely complex Estate, encompassing over 500 buildings of different sizes, ages and typologies, over 100 of which are 'Listed' (protected by legislation from demolition or inconsiderate refurbishment). The presentation demonstrated the extreme complexity of seeking a strategy across the hugely varied estate, spread across the city and already incorporating multiple different strategies for low-energy operation. Community-engaged heating and power generation were discussed as a potential solution for some campus locations.
Q1. asked whether a guidebook has been prepared yet for the carbon neutrality of any campus. It was made known that the guidebook is ready for one campus location and that other guides are being prepared based on an archetype approach.

Also discussed was the uncontrollable energy demands that are deemed as unavoidable carbon emissions, which need to be accounted for and compensated. There are also ideas around sharing heat and electricity with the city partners and around those buildings near university campuses requiring further investigation. The level of investment in a campus of this size and complexity is huge, especially around the retrofit of buildings, but benefits can be shown immediately in operating costs.

Concluding comments

The presented projects exemplify the growing commitment of universities worldwide to achieve carbon neutrality and sustainability. They reflected diverse strategies and approaches tailored to the unique challenges and contexts faced by each institution.

Robert Koester, Ball State University, demonstrated the efficacy of leveraging the voluntary carbon market to fund carbon reduction projects. Despite political hurdles, the university has successfully managed the decarbonisation of its Estate, showcasing the potential for public institutions in traditionally fossil fuel-reliant regions to drive meaningful change.

TU Delft's comprehensive approach, as highlighted by Deirdre van Gameren, showcased the importance of embedding sustainability practices at all levels of the institution. By imposing carbon reporting requirements on suppliers, they are encouraging a broader culture of sustainability within their supply chains. There is also a common goal at all levels where not only Estate management is involved, with university research group leaders and management also being part of this drive towards sustainability and low-carbon living. The responsibility for achieving a Net Zero campus lies with all those using the university campus regardless of the type of user be they a teacher, administrator, student or supplier.

Sara Dorregaray-Oyaregui's project at the University of Navarra focused on gathering data for informed decision-making, illustrating the importance of data-driven sustainability strategies. Despite challenges posed by the age of the buildings, the university recognises the importance of careful modelling and planning to achieve carbon neutrality.

Julio Bros Williamson, from the University of Edinburgh, emphasised the complexity of achieving carbon neutrality in a large, diverse and complex set of campuses with buildings ranging from the historic to the very modern. The holistic approach adapted by Edinburgh to retrofitting and energy management, including community engagement and partnerships with the city, highlights the importance of collaboration in sustainability efforts. The implementation of clear guidance into the retrofit of buildings needs to be balanced with the use of low-carbon heating methods such as heat pumps and renewables. Some buildings will require more fabric interventions to reduce energy demand, but others will have to rely on low-carbon heating technology and this should be determined by the building classification and archetype it is placed in to have a balanced approach to the net-zero performance required. With such a heterogeneous range of buildings one approach may be to model options to attribute a net-zero potential score for a building. Optimised generic solutions can be applied to different building archetypes but ultimately the unique design of each building will influence the success of remedial interventions as will the way it is used and managed over time. What is most important is that the performance improvement for different buildings is monitored within a clear and carefully followed, long-term framework for action on a campus and that lessons are iteratively learnt and carried forward to ensure the continual reduction of the footprint of the facilities over time.

One recurring question asked after all presentations was the role of travel amongst students and staff at universities and how it was accounted for in the overall sustainability roadmap and net-zero considerations. At *Ball State* student travel was not accounted for at present and the speaker said that although this is not done at present, there are plans to include this in future carbon emissions accounts. However, faculty travel is accounted for when going to conferences, meetings and field trips. At *Delft TU* the issue of student and faculty travel brought up the argument about having enough accommodation near the university buildings and campuses for staff and students which is often not the case for most universities. It came to light that most students at TU Delft either live “in the neighbourhood” of the university or close by within the city of Delft, and either walk, bike, or take public transport to the university. For staff, the case is different, and many members of staff travel from farther away. To curb carbon emissions from the daily travel of employees, there are plans to introduce public transport cards for employees and also create regulated parking spaces for employees (where other citizens will not be able to park in future). Employees would then have to pay according to whether they use the public transport card or the parking, which is expected to regulate some parking and car travel. *At Navarra University* this was a different issue, as the three campuses are in different cities across the northern and central area of Spain and students don’t do inter-campus travel. However, the university has many international students, and it is complicated to account for the carbon footprint of each student immediately. It is

also a challenge to reduce the carbon footprint from international travel while maintaining the international spirit of the university.

Overall, the presentations and projects highlight the multifaceted nature of achieving carbon neutrality in universities, including the need for a long term vision for the establishment and its local and international campuses. Key to implementing that vision is a robust, actionable and effective policy framework and strategies. Underpinning the improvement in building performance and the meeting of related targets must be effective data collection and management systems integrated into sustainable practices at all levels of the institution and for all stakeholders in its operations. Of critical importance was the local and regional environmental, infrastructural, economic and cultural context of each university as well as the political and structural policy challenges faced by each organisation in the pursuit of the low carbon operation of their buildings.

It is also worth mentioning what was not mentioned in the case studies of this workshop was the role of individuals as environmental pioneers pushing forward a sustainability or low carbon agenda in each of the universities. It is often the dogged actions of one or two people in an organisation who push through forward looking agendas. In the case of often highly funded and influential universities the resulting Beacon organisations can change the progress of entire cities and regions in the wake of their own achievements. Perhaps a next step might be towards a whole conference on Net Zero Campuses.

WORKSHOP 6: ADAPTIVE THERMAL COMFORT

Chairs: Fergus Nicol Nicol and Eliza Hotchkiss, NREL - National Renewable Energy Lab. USA
Rapporteur – Caroline Vosburgh, Napier University, Edinburgh

This workshop looked at alternative methods of achieving thermal comfort as a substitute or complement to HVAC and similar systems, commonly used and often mandated in commercial building codes in many countries. Traditional and modern methods and approaches were examined in different contexts, including several Northern European countries and Singapore. A new local Edinburgh project was presented – an Archive House – an EnerPHit Scottish Net Zero public sector standard building due on-site in spring 2024.

Romina Rissetto of Karlsruhe Institute of Technology Germany and Gesche Heubner of University College London presented a paper on: *Mixed Methods Approach to understand occupants' acceptance and use of personal ceiling fan – a field case study.* Ceiling fans are a traditional method of adaptive thermal comfort. Sufficient approaches to thermal comfort should be explored as a cost-effective alternative to AC. This study included semi-structured interviews and monitoring over one year to ascertain the effectiveness of personal ceiling fans in an office context.

- Use of personal environment control systems to reduce cooling energy impacts.
- Investigated the occupant's expectations, information and knowledge of ceiling fans.
- Indoor environmental air quality was investigated from the viewpoint of the occupants.
- Results showed that aligning expectations with personal control systems increased thermal comfort and knowledge of building design.
- Interactions with the fan did not always correlate with the knowledge and expectations of thermal comfort. More 'training' of the users on how best to use the ceiling fan is likely needed to improve effectiveness and more research.
- Personal control was found to be very effective as thermal comfort is subjective to individuals and at different times. Air quality perception improved with the increased autonomy of the fan controls.
- Fresh air from open windows was prefered by some in the study.
- More research is needed that correlates building measurements with occupant feedback studies.

Zheng Kai, Aceson Han and Oh Yu Fang of the Singapore University of Technology and Design contributed a presentation on a study of a evaporative cooling systems in a school in Singapore, a hot, humid climate with no seasons requiring no energy for heating but significant energy demand for cooling across the seasons. Local Singaporeans are acclimatised to high humidity of 80-90% and temperatures of 25-30^{o}C. These levels are significantly higher than the thermal comfort level for northern Europeans. Operational carbon, scope two, was examined as limited research has been done on evaporative cooling strategies in humid climates. Computational fluid dynamics experiments were done, along with comfort surveys.

- Dry mist study – too much direct sunshine and poor building design led to unfavourable results.
- Water drip window study – efficient system for plants; however, it was inconclusive as an approach in this study. Mosquitos were found to be breading in standing water if troughs and tanks were not adequately covered. More research is needed.
- Outdoor cooling applications such as white and cooling paints were found to be effective.
- CFD (computational fluid dynamics) of wind found that louvred blinds were more effective than roller blinds; however, more work needs to be done in the area.
- All methods were looked at in isolation; however, combinations of multiple approaches look promising and should be studied further.

Seyed Hooshmand, Mino Rodrigues et el. Karlsruhe Institute of Technology, Germany presented a study on *Designing local radiant heating devices for different body parts: effects on skin temperatures.*

This study was conducted at a test facility with ten students, aged 20-30, in a German University where specialist wooden structures were made for specific body parts with heated fabrics on 18 different body parts, including head, face, neck, chest, arms, legs, hands, feet, back and pelvis.

- No significant difference was perceived between the sexes.
- The base room ambient temperature was 19.5 ^{o}C, and the target skin temperature for radiant heating was 26^{o}C.
- A wide range of preferences were noted, with the upper body and core found to be the most effective in influencing thermal comfort. The neck-warming device was markedly positive.
- Significant energy savings can be made by targeting radiant heat to specific body parts.
- Local radiant heat is not a new concept, and as Fergus Nicol noted, open fires have been used for centuries. Low-temperature radiant ceiling heat has been found effective.
- More research is needed in local radiant heat modelling.

See also: Hooshmand, S. M., Zhang, H., Javidanfar, H., Zhai, Y., & Wagner, A. (2023). A review of local radiant heating systems and their effects on thermal comfort and sensation. *Energy and Buildings*, *296*, 113331. https://doi.org/10.1016/j.enbuild.2023.113331

Bernadette Csaszar, (with Oliver Kinane and Richard O'Hegerty) of University of Dublin, Ireland presented a study on *Balancing aesthetics, operational energy and embodies carbon emissions: analysis and guidance.* This paper analysed the embodied and operational carbon emissions associated with a municipal 2015 building in Dublin, Ireland. When a whole-life carbon analysis was done, it was found insufficient when a worst-case scenario was analysed. Significant energy savings can be made if more robust approaches are used.

- The building was promoted as having high environmental standards yet had significant embodied carbon: steel and cement, a particular issue in Ireland.
- Thermal modelling evaluated and identified the weak points in the building.
- A significant performance gap was noted – the windows had extreme thermal bringing issues. Improperly installed windows are an unusual problem in colder climates on the continent, where colder winters and high-performance x3 glazed windows are more common. The tender process was found not to be robust enough.

- The aesthetics of the building design were found to be more important in the designing phase than the thermal performance.
- Current thermal measurements were based on models as sensors were recently installed – analysis of on-site measurements is ongoing.

Jumping the hurdles of a true Net Zero construction

Samantha McCabe – director of Sustainability, Catriona Kinghorn. Oberlanders Architects LLP, UK presented an overview of the first public building in Scotland to be of the new Scottish EnerPhit standard – aiming to be an exemplar of reuse and retrofit. A new Archive House in Bonnyrigg, a SE suburb of Edinburgh. A challenging project, due to be on-site in Spring 2024, with completion in 2026. Input from Scottish Futures Trust.

- The existing building is being retrofitted, retaining as much of the existing structure as possible. New-build extensions are added for housing specialist collections, a public archive search room & library, and staff offices – all with specific requirements.
- Ten plus building standards and models are needed to account for the existing building, extensions and different temperature zones. However, the whole building simulations must be used in modelling, amounting to a significant amount of time-consuming paperwork for compliance.
- The Net Zero standards have some inherent contradictions and are not entirely compatible with each other, making prioritising what aspects of the building very challenging. As the building is an archive, a four-hour fire protection and a cold store - 10^{o}C are needed. Achieving the OC and EC targets is almost impossible. There is little or no flexibility considering the specialist nature of the building and its use.
- Operational Carbon and Embodied carbon are inherently linked; however, there is no way in the current methodologies for trade-offs between the two.
- There is a need to step back and look at the larger picture. Are we asking the right questions?
- Post Occupancy evaluations and client feedback will likely be minimised as they are not in the architect's official brief.

This study shows how very important it is to match the requirements of client, site, climate and the regulations. More on the building can be found at: https://www.oberlanders.co.uk/news/historic-environment-scotland-unveils-plans-for-new-archive-house

FINAL PANEL SESSION 8 – NEW DIRECTIONS FOR NET ZERO

Chair: Paul Dorfman and Ulrike Passe

Rapporteur: Magdalena Blazusiak, Robert Gordon University, Aberdeen

Panel: Vanessa Gomes, Rolf Fischnecht, Daniel Overbey, Julio Bros-Williamson

Ulrike Passe lead on the questions relating to buildings and Paul Dorfman on the general carbon questions, relating in particular to energy issues.

The aim of this Panel Session was to draw out key outcomes, questions and answers from the two days of the Conference, to stimulate a lively debate on the ways forward that might actually impact policies and support the process of transition to Net Zero Carbon by 2050.

Q1. focused on who decides on what Net Zero targets are and whether the priorities are right.
Rolf Fischnecht proposed that the policy should define the targets, which in this instance would be a carbon neutrality with validity for both construction and operation of the buildings taking cognisance of upfront carbon budget. The priority should always be in carbon reduction before considering balancing emissions with negative emissions, for buildings designed and constructed within planetary boundaries, resilient to climate adaptation and change.
Daniel Overbey added the importance of the involvement of markets, seeing increase in corporate interest in achieving Net Zero in practice. The focus should shift to carbon from the net zero energy, which prevails now and is important to achieving the goal. Wide stakeholder group should be invited to discuss ESG finance, corporate enterprise model, carbon offsetting and credits that are location specific, carbon intensity of the transportation sector, energy aggregators and smart grid systems.
Paul Dorfman added the inclusion of people in the decision-making processes, through participatory democracy.
Daniel Overbey concluded by remarking on the importance of consumer benefit and economic benefit as well as addressing intended performance outcomes of carbon reductions.
Julio Bros-Williamson highlighted that the strategy should not simply concentrate on decarbonising of the built environment based on building targets but consider communities, their needs and participation. The targets should be set by the communities living in the buildings but equally with the understanding of the industry.
Ulrike Passe added the importance of the participatory action and inclusion of the communities and the general public in shaping of the standards. Another response from the audience queried whether the targets should be set by the scientists and people with technical knowledge and scientific understanding of the requirements to reach required carbon reductions.

Q2. considered what issues matter most for buildings and communities in unpredictable futures, whether Net Zero or resilience. The panel agreed that meeting Net Zero targets and resilient built environment do not need to be mutually exclusive. These both aspects are important to be considered together, in a balanced approach, promoting adaptive comfort and passive design principles. Resilience cannot be separated from sustainability and collective approach to achieve both should be the way forward.
Paul Dorfman added the issue of energy supply resilience and the understanding of the community resilience. The Chairs added a remark of the recognizing of the decentralised grid and opportunities of renewable decentralised systems supporting energy supply at local scale, with flexible, distributive energy structures. There was a remark on the level of trust required to enforce targets and ensure welfare of the individuals. The governments need to become better at communicating with the communities on the progress and future development addressing the needs of local neighbourhoods.
The feedback from the audience addressed local and regional resilience, that can drive net zero aspirations and ensure quality of spaces, promoting healthy living environments. The ambition for addressing resilience should not be mistaken with accepting of the predicted carbon trajectory but rather used as the drive for mitigation to achieve best results within the time identified by the scientific community. The resilience however can be unequal and dependant on affordability.
Q3. concerned reliance on decarbonised grid to meet required carbon reductions.
Daniel Overbey discussed forecast of decarbonised grid internationally and the reliance on fossil fuels and carbon in energy production.
Rolf Fischnecht added that even though grid decarbonisation is an important step towards reaching carbon reductions worldwide, electricity is not the only technology responsible for the extensive

carbon emissions in the construction sector. Operational energy, transport, material manufacture, all have an impact on the overall emissions of the industry, therefore reliance on decarbonised grid is not sufficient and wider implications of promotion of low carbon solutions such as nuclear power in decarbonising electricity need to be carefully considered. Multiple environmental indicators are required when assessing development, to reduce the likelihood of any unintended consequences.
Julio Bros-Williamson added that in some instances reliance on decarbonised grid will be higher, where thermal efficiency measures may be dictated by the building physics and conservation status of some of the historic buildings, thus supporting balanced, evidence-based approach.
Q4. asked what policies work for the buildings and communities, with the comment from the audience on the assumption that some failed policies do not work, without considering implementation strategies and their limitations, giving the example of the heat pump intake in the UK. Denmark and Finland have a directive on the carbon budget per square meter per year for buildings, with tools and data available to support implementation of the target, mandating Lifecycle Carbon Assessment. It is imperative to have a clear definition of the Net Zero carbon and what it entails.
Ulrike Passe asked where the system boundary should be set for understanding carbon targets and standards within context.
Jimmy Jia reflected on the issue of standards not fully addressing implementation and problem of debating definitions and not agreeing on the baseline of the standards, affecting their success.
Daniel Overbey discussed outcomes of the policy and how to ensure that these standards are met in practice, supported through evidence-based approach, with knowledge and data availability supporting behavioural change, describing the principle of provision of smart meters in households, providing results where performance reporting and disclosure are mandated.
Sue Roaf added a comment of the relevance of rooftop solar and water heating and perhaps introducing annual reporting of building carbon emissions to address discrepancy between design assumptions and operation, looking at the targets from in use perspective.
Timothee de Toldi commented on the purpose and definition of system boundaries and how in material selection the choices should reflect eco, geo and bio system requirement and ecological demand to provide a particular material, assessing intensity from donor perspective, not the receiver; the latter being what the carbon reductions and cost optimisations models currently promote.
In summary *Daniel Overbey* highlighted that the resilience needs to consider communities and promote equality.
Rolf Fischnecht added the importance of embodied carbon.
Vanessa Gomes focused on appropriate engineering metrics and LCA.
Julio Bros-Williamson stressed the importance of inclusion of the existing building stock and interventions required to meet the Net Zero targets.

The Conference closed with thanks being given to all those who had organised it – those who had serviced it and those who attended it.

RANDOM REFLECTIONS AFTER ICARB 2023:

The following includes miscellany of random reflections sent to the organisers by some delegates after the conclusion of the conference. For readers who are looking to understand different viewpoints on the many and complex challenges posed by the need to rapidly decarbonise our buildings and communities you may find some or all of the following interesting. They inevitably reflect the priorities of those who replied to requests for reflections, and show that Net Zero issues can be contentious!

A LACK OF URGENCY

One might argue that this may not be a requirement for a Carbon Accounting conference but, overall, there was a lack of urgency in how people are responding to transition requirements. The estimated 'for-ever' carbon budget in 2021 that we are permitted to emit to retain a 50:50 chance of limiting temp rise to 1.7degC is 716 $GTCO_2$. Beyond 1.7degC we get into tipping point territory and the wheels could come off quickly. We are currently chomping through this at 1% per month – so 2029 or so we reach the tipping points. That presents a sense of urgency which was absent from many of the talks.

THE ZERO CARBON GRID

It seems that government policies are putting all their efforts into the electrification of our building stock and the transportation sector and the decarbonising of the supporting grid. Political ambitions for a Net Zero future appear to hinge on the decarbonisation of the grid.

Western societies have not been able to address the urgent need for energy conservation and efficiency to the extent necessary to reduce CO_2 emissions as far as needed to meet Paris targets, thus grid decarbonisation seems to be the only pathway saving us from climate doom. It was also emphasized that projections suggest gas and liquids will be a part of our world's primary energy mix into the 2050s.

We can't have zero-emission electricity until the entire grid has reached zero emissions, and that is a goal that we need to continue to be focused on. Mark Jacobson presented calculations for the world showing that 100% renewable clean energy is possible everywhere. Those calculations would need to be checked to verify this claim, but his talk showed, that even though the technology exists, what is missing is the will to shift to a Zero Carbon grid in too many countries.

We need far sighted political policy infrastructures to secure clean, safe, affordable, sustainable, low-carbon energy to power industry, transport, homes and businesses. This requires a multi-faceted vision including the expansion of renewable energy in all sectors, rapid growth and modernisation of the electricity grid, energy conservation and efficiency, rapidly evolving storage technology, interconnection, and market innovation from supply to service provision. Built environment and transport infrastructure are key. The clean energy transition powered by modern renewables can also act to turbocharge the UK economy and the Net Zero transition. We must shift away from energy-based metrics for "net-zero" and toward a total carbon intensity metric.

ENERGY INFRASTRUCTURE

The renewable energy transition needs a complete redesign and re-building of the energy distribution/transmission infrastructure but a woeful lack of investment has held progress back decades. If the UK government was willing to spend nearly £100 billion on the HS2 train – why have they put so little into rebuilding the energy grid?

AN INTERACTIVE GRID

Net Zero targets will require a combination of public and private cooperation and greater grid interactivity between the electrified buildings and vehicles. This requires users – prosumers as Matthias Haase describes them – to have first class data on which to base decisions on the optimisation of their choices and behaviours. Property managers and homeowners need real-time data feedback loops.

MANAGING LOADS

When energy is used matters as much as how much is used. Utilities supply energy in different ways throughout the day and year. It was noted that behaviours matter enormously but there is little policy effort going into the orchestration/synchronisation of building energy demand and supply profiles. An example of the lack of joined up thinking is exemplified by the pushing of lightweight timber buildings with no thermal mass the store thermal energy that will enable temperature time lags to be used to avoid demanding energy during periods of peak demand. If demand exceeds

supply the grid fails but no account is being taken of designing thermal resilience into the new building stock.

ENERGY AGGREGATORS

Buildings can only play an impactful role in creating grid stability in a renewable-dominant grid when coordinated by an entity that can aggregate buildings as a single resource. The aggregated load managed by such an entity that can shift or respond to utility signals. Energy aggregators may well be a disruptive technology to the regulated monopoly of centralized utility-scale energy generation, harnessing grid level energy storage to ride peaks of demand from the built environment. Can energy aggregators and their storage capacity become part of Net Zero community planning?

SOLAR ENERGY GENERATION

Optimistic insights were provided by Ian Marius Peters from Helmholtz Institute Germany, that PV electricity has become the cheapest electricity resource in history. This information should be trumpeted as a main message from this conference: PV is cheap and its life cycle assessment including embodied carbon does not change this statement.

Despite this fact PV and solar hot water systems contributions are systematically downplayed and almost discouraged in government policy environments and the building regulations system. Matthias Haase demonstrated that the optimal amount of PV to put on a roof was not what covers demand but as much as you can fit on the roof. John Forster highlighted how UK solar generation policies that flip-flopped had put many solar companies out of business and created a harsh environment in which solar roofing companies operate today.

SOLAR ENERGY EDUCATION

John Forster provided eye-opening retirement numbers for skilled labourers in the construction industry who are largely over fifty years old, and he predicted that in the UK skilled labour to address the energy transition was rapidly disappearing. The challenge is to educate the next generations of building workers in both low-energy construction and building integrated renewable energy skills.

BIOMASS ENERGY GENERATION

When the wind doesn't blow and the sun doesn't shine in winter you have to burn stuff to power and heat buildings. In the transition to a fully renewable world when the next generation of marine and tidal and double pumped hydro generators come online, oil and gas are still being burnt. A strong case was made that biomass with carbon capture and storage (BECCS) technologies is the least harmful to the climate of all the fossil fuels and hence will be an important transitional technology, necessarily in the presence of strong standards and guidelines that ensure the environmental impacts of the processes are well reported, regulated and managed.

Concerns on the other hand were raised that biomass generators account for a cycle of somewhere between 6 and 30 years, depending on the life cycle of a tree. So they emit, warm things up and then over a period soak up emissions and return things to near neutrality. At some point, their warming contribution pokes things above this tipping point, and returning the atmosphere to the existing equilibrium may not be credible using their mechanism. That they are also emitting near neutrality is also important; their stated emission factor for Drax was 0.098 kgCO2/kWh – so they are betting the house on BECCS and here it depends on what stance you take on carbon capture.

BECCS seems to be the newest favoured technology for some, but how carbon harvested in the US can, or even should contribute to carbon capture in the UK remained a mystery to one audience member.

CARBON CAPTURE AND STORAGE (CCS)

CCS is a Marmite Technology like biomass burning. Some people like Dieter Helm are enthusiastic supporters while others are the opposite. One argument was that in the UK it will not work without massive investment in the plumbing to connect production sites to the North Sea. Most countries like India and China have only limited geographical features to take advantage of this in any case. Surely, it was argued, if we are spending big on infrastructure we should be developing something with global potential? Others might say why?

Mark Jacobson was strongly opposed to CCS and explained why using an example with a pipeline that is over 2000 miles long to dump the residue of the process into long term storage. Using such an extreme example was not convincing for some. A sensible central position was taken by Camilla Thompson showing a case study in Scotland where a local storage repository can be coupled with adjacent waste to energy generation plants in a bespoke and optimised process turning waste that would otherwise go to landfill into a useful energy generation opportunity. CCS it seems can be seen as suitable technology in certain circumstances.

NUCLEAR

There was no support from the audience for nuclear. It was rejected as a viable solution to emissions reduction by all including Deiter Helm and Mark Jaconson, with good reason as Paul Dorman reiterated. The IPCC AR6 2023 reports renewables as 10 times more effective than nuclear at mitigating CO_2 emissions to 2030 (a critical time frame - and by then much better). The UK Govt Dept BEIS reports it takes up to 17 years to build one new nuclear station and it was rightly argued that we just don't have time for new nuclear. New nuclear is at least four times more expensive than renewables. So, with millions struggling under the cost-of-living and energy crisis, stuffing huge sums of public money into the deep pockets of nuclear corporations won't look good to people in policies and the press.

WIND

Wind is a crucial contributor to our Net Zero futures but progress in on-shore wind farms is now being stalled by planning barriers.

MINIMISING ENERGY DEMAND

Despite the fact that central governments rely on grid decarbonisation and too often ignore the need for major reductions from existing buildings to reduce their demand for energy through efficiency upgrades, these play a vital part in actually achieving a low-carbon future for countries.

In the UK over the last decade, retrofitting of existing buildings has been a car crash in the last decade or so. Poorly managed and planned by UK and local Government, incentives are made to implement certain methods and technology, and all too often the financial models used and the coordination of their delivery have stalled progress.

GOVERNMENT POLICY ON LOW CARBON BUILDINGS

Government Policy has been repeatedly highjacked by well-funded and heavily lobbied for vested interests of different groups. At a government level in Scotland, the Passive House movement has railroaded the Scottish Government into moving towards adopting their standards as mandatory regardless of the fact that they use a crude building design model that does not take into account the height of spaces in a building, the benefits of natural ventilation or thermal mass etc. The mandating of its very 20th century mantras will inevitably stifle the types of innovation that will be vital to the creation of the next generation of future facing, climate resilient buildings that will be able to keep occupants comfortable in a heating world. In addition, the Passive House methodology uses largely discredited Steady State thermal comfort standards that were developed by the US air-conditioning industry in the 20th century and no longer reflect the perceptions of temperatures, even today in Northern Europe. By including the assumption that no one can be comfortable at a temperature above 26^0C (ridiculous) they are pushing the industry into needing more and more

mechanical equipment to meet the standards. This happens across the board with the current regulations that are written by HVAC engineers who make their money by putting equipment into buildings and are ill-educated on genuinely passive design.

Jonathan Porritt from the Forum for Future had a very straightforward response, to why western societies have such a hard time changing: the capitalist market economy stands in the way of change. UK policy is in hock to those who lobby hardest and pay most.

BUILDING REGULATIONS

The conference laid bare the fact that Building Regulations in the UK are embarrassingly unfit for purpose resulting is backward-looking regulations churned out by a system that is grindingly slow at updating its assumptions and targets. Targets enshrined in legislation are not set consistently across countries in Europe and the lack of compatibility means that comparisons in performance are not possible.

As the conference took place in Scotland, the Scottish Government provided updates on heating transition and building codes. Not a lot of ground-breaking new information was provided here. Existing buildings still need more attention and the system seems stuck in the 1990s with their main training emphasis being on issues like air pressure testing of new builds that should have been mandated for decades. Present building codes tend to favour lightweight construction, predominantly featuring light-framed and timber-based structures. However, these structures lack substantial heat barriers due to their absence of thermal inertia or, in some cases, exacerbate overheating concerns. The regulations appear to be also subject to the priorities and prejudices of those who write them, for instance in the promotion of often unnecessary mechanical systems and the barriers placed in them to the broader uptake of building integrated solar systems.

BUILDING REGULATIONS TONE DEAF TO THE CHALLENGES

The building regulations are inevitably a channel for the implementation of government priorities, not least at the moment of the electrification of the grid. This has resulted in a fixation with electric domestic systems and heat pumps in particular**.** There is a huge problem with this as heat pumps are typically seen as a low-temperature heating system of the type suitable for modern well-insulated envelopes and for use in underfloor heating systems. Many of the buildings in Scotland are simply not suitable for the installation of heat pumps at an affordable price. The cost of upgrading their performance is already prohibitive before the high cost heat pump is installed. Promoters of heat pumps claim (all these assumptions based on conversations or presentations at ICARB) that people will HAVE to insulate their homes and pay to install and run heat pumps – turning a deaf ear to those who simply say “we cannot afford it”. In rural communities where people have ample local good dry wood and currently survive winters by burning local wood in efficient stoves.

HEAT NETWORKS

Heat Networks that are favoured by the engineers and the politicians they influence are also challenging. The very high construction costs and consequent heat costs are prohibitive for the poorest in society as we have seen with people devastated by heating bills of over £1000 for a supply they are mandated to accept. One reason Heat Networks are not being adopted in modern developments is that the first houses built need to cover the costs for the capacity for the whole final development. Another reason is that highly insulated homes do not need much heat. A third reason is that the world has moved on from the mantra of ‘Heat the Building’ to ‘Heat the Person’. A small local heater or cooler can do that at a fraction of the price than a full Heat Network can.

CARBON MARKETS

The panel reflected on the matter of policy vs incentives. In particular, how might the market drive transformation if we should find a way to successfully commoditise carbon?

CARBON ACCOUNTING QUERIES

A major point of discussion throughout the conference regarded system boundaries for targets and standards. Simply the notion of defining the system boundaries was wrought with debate and valid concerns. The stages and scopes are everything. Yet one enterprise's Scope 3 is another enterprise's Scope 1 and 2 emissions. Life cycle assessment is the new frontier, and that's where harmonization of metrics needs to happen. How long should the life cycle be? Perhaps training for the designing professions on carbon accounting might be made mandatory.

EMBODIED ENERGY V. WHOLE LIFE ENERGY

One LCA expert pointed out that to consider Embodied Energy as the only criterion for Net Zero measurement was ludicrous as what matters is the Total Carbon impact of a building over time (typically 60 years) including operational energy. She echoed the thinking of many who also shared an understanding throughout the conference how important the issue of resilience is, and not least how it affects the thermal conditions of occupants in buildings, particularly during extreme weather.

DESIGNING FOR RESILIENCE

The final panel briefly touched on facets of this prompt. The balance of the discussion seemed to suggest that there are many ways to define such benefits; and that it is more possible today than ever. The whole subjects of Resilience and Sufficiency are examples of where we need to put the tools in the hands of project teams with basic sustainable design competencies.

Many were taken by the idea put forward by Daniel Overby and Alex Wilson of *Passive Survivability*. They listed three requirements for Passive Survivability including public access to consistently produced downscaled climate projection data; consensus on how passive survivability is measured and assessed and that all new buildings need to be simulated with the "HVAC/off" functionality to see how they perform without mechanical heating or cooling. They pointed out that advanced passive solar heating and cooling simulations are easily accessed using early-stage design and analysis platforms that validate building energy modelling software.

Resilience prompts us to *raise the floor* quickly so that those who shoulder the greatest burdens of climate change and can least afford to do so are protected. Eliza Hotchkiss demonstrated that the USA is leading our understanding of what resilience in buildings might look like, probably as the reality that climate crisis awareness there is heightened due to the ever more extreme weather events they are enduring. Velux provided a case study of a Copenhagen 'Living Places' that clearly demonstrated that we can account for energy sufficiency and resilience at the design stage for features like shading, thermal mass and natural ventilation without using engineer's metrics for mechanical efficiency.

DESIGNING FOR ENERGY SUFFIENCY

Sue Roaf added that design for resilience and sufficiency a two faces of the same challenge. If you measure Sufficiency as the percentage of the year that the building can be run on local natural energy, then this requires a thermally well-behaved building that does not gain or lose heat rapidly requiring constant mechanical conditioning to avoid discomfort. Rajan Rawal's paper on Indian offices demonstrated that up to 50% of the energy used can be saved by running buildings in natural ventilation and mixed modes using fans, offering a radical reduction in emissions. However, building regulations do not even mention a requirement for natural ventilation. Yet the benefits of good shading, natural ventilation and energy storage in structures are key to Net Zero Buildings and are almost ignored in regulations and many design simulation packages, not least by the Passive House movement.

THE CHANGING CLIMATE CONTEXT

In light of these challenges, the building and construction sector must adapt and ensure passive survivability within future climate conditions. A pressing issue is the growing heat stress, which has become a major public health concern. This is primarily attributed to the increasingly intense and frequent heatwaves, coupled with a steadily warming climate.

CLIMATE RESILEINCE

Timothee Di Toldi well deserved to win the ICARB 2023 best paper prize for a thorough study of the benefit of thermal mass and natural ventilation even in the warming climate of France. Even when heat pumps might be the most immediate solution for the masses of buildings to connect to the decarbonized grid, resilience considerations will continue to address passive design strategies in the energy transition. Only a building where windows can be opened and a thoroughly designed thermal enclosure can remain inhabitable when the power goes out in an erratic wind storm, and those will increase as this summer of 2023 already has shown.

NEGATIVE TRENDS – GROWING DEMAND FOR AIR CONDITIONING

To combat rising temperatures, there is a growing inclination towards using air conditioning systems for thermal comfort. However, this approach brings forth several drawbacks, including heightened emissions (indirect operational emissions from electricity production, direct operational emissions from refrigerant leakage, and embodied emissions from equipment manufacture), exacerbation of urban heat island effects (from the use of exterior air as a heat sink, and the GHG effect of refrigerant leakage), the perpetuation of social inequalities due to high costs, and potential operational challenges during peak demand periods, particularly during heatwaves (heat-waves are high pressure events, often coupled with droughts, which both pose constraints on wind electricity production –i.e., absence of wind during high pressure events–, nuclear electricity production –i.e., thermal discharges limitations within river systems–, and hydroelectricity production).

BARRIERS TO PASSIVE COOLING

Current legislation and building codes do not establish clear targets for passive survivability and thermal comfort. Although recognized as an emerging challenge and occasionally encouraged (e.g., through passive survivability credits within the LEED BD+C accreditation system or considerations like Cooling Degree Days in the French RE2020), there is a lack of direct incentives for industry stakeholders to implement such strategies.

b. Predictive Gaps: There is a notable absence of a standardised framework that academia, practitioners, and legislators can rely upon to predict the performance and adequacy of passive cooling strategies through quantitative analyses. Methodologies and datasets must be made readily available on a large scale to enable policymakers and academia to gain valuable insights for planning and implementation.

c. Normative Gaps: While certain niches within the research community have addressed this issue, the private sector predominantly lacks the technical expertise required to choose appropriate strategies and implement them effectively. Matters related to natural ventilation, thermal mass distribution, and other relevant aspects have been somewhat neglected. Bridging this knowledge gap necessitates widespread information sharing and the establishment of dedicated platforms to foster the development of these strategies. Once the broader public, including future building occupants, becomes better informed (addressing the "predictive gap" mentioned earlier), they can exert pressure on policymakers to promote such platforms and encourage structured documentation of strategies, both for retrofitting existing structures and constructing new ones.

NATURAL VENTILATION

Rajan Rawal's paper showed that for India a clear and immediate solution exists to radically reduce emissions from buildings, in particular offices, and that is to run them for as much of the year as possible on natural ventilation or natural ventilation with fan power as well. This can cut up to 50%

of energy use without creating discomfort if happening in climatically well designed passive buildings.
The move to Mixed-mode buildings is ignored by Building Regulations, Comfort Standards and the widely used design models that make related decisions overly complex for ordinary design offices.

THE UK NET ZERO STANDARD

The UK Net Zero Carbon Standard talk was odd as it did not reference in any shape or form the Code for Sustainable Homes; a ready-made standard, with a fabric first, passive approach that was worked on by countless Academics, house builders, policy makers etc. between 2002 and 2012, or the efforts done by the Zero Carbon Hub around the same period. If they want to adopt something quickly, dust this down and restart the implementation cycle. Also, if it is not all about minimum standards, it will make little difference – the housebuilders will continue to build to minimum standards. The Technical Steering Group for the Net Zero Standard seems to have grouped mainly English consultancy companies, architects, TIER 1 contractors and chartered bodies (as seen in the selected members - https://www.nzcbuildings.co.uk/contributors). The standard fails to include issues concerning other regions, such as Scotland and has minimal participation from academics researching the field (only 10 including only 3 from Scotland). Once again, another example of a hijacked government backed initiative focused on the problems in England and driven by commercial for-profit companies.

EQUITY

A point was made in the final plenary that decarbonisation efforts in the West were being undermined by the level of coal burning in India and China. This points to an issue of equity, in my view, rather than one of despondency. The West has gained an economic advantage from historical emissions which have contributed 50-60% of the global total. Decarbonisation efforts should reflect this, and the West should be decarbonising at a much faster rate than agreed in Paris or Glasgow. This is only possible if we recognise the shibboleth of Western lifestyles – average electricity consumption is circa 0.1, 1, 4 and 14 MWh per person pa in Tanzania, India, Europe and the US respectively. It would have been interesting to hear someone mention this, concerning affluence, the need for de-growth etc.

NEW MATERIALS

Exciting developments in new materials were included in papers and pointed the way for instance to low carbon high mass material developments, bio-engineering of new materials and a mature understanding of the whole-life environmental impacts of materials used in construction and energy generation. It was flagged that with the pressure from certain quarters to push for low embodied energy materials low carbon and high mass materials may be excluded from mandated approaches, for example, natural fibre insulation products, and low carbon bricks and cement that are now coming to market. The design simulation menus of materials must also keep pace with such exciting new developments.

CAMPUS AND CITY LEVEL PROGRAMMES

Further optimism came from IFC/World Bank Prashant Kapoor as he presented the EDGE Tool, a tool that has had real success reducing emissions in cities around the world. Julio Bros-Williamson highlighted that in the Net Zero Campus studies a key factor in implementing any endeavour to radically reduce emissions from a building or community is the existence of a robust and actionable policy framework with effective strategies.

Underpinning the improvement in building performance benchmarking and the meeting of related targets must be effective data collection and management systems integrated into sustainable practices at all levels of the institution and for all stakeholders in its operations. No two buildings or communities are the same. Their local and regional environmental, infrastructural,

economic and cultural contexts, as well as the political and structural policy frameworks they operate in, are all unique. Perhaps a good place to end these reflections is with Prashant Kapoor's advice that what is needed is the combination of knowledge, financial resources, and political willpower to bring our cities, buildings and communities on a Paris-aligned pathway.

PEOPLE AND BEHAVIOURS AS SOLUTIONS

Reflections from Workshop 2 looked also at the big pictures. It was reported that going from the discussions in the Workshop on Behaviours and then into Sessions 4 and 5 was very interesting. Those presentations were all from men, and though they all gave great lectures, there was little or no questioning (explicit or implicit) of the engineering-first market-led narratives, not even from Jonathan Porritt (who spoke approvingly about 'Insulate Britain', without realising that it clearly involved ideas of corporate capture). And therefore no discussion of that central point: W*hy* are we using all this energy in the first place? Where it is truly useful, and where is it just poor habits. Where were the thermal physiologists were showing how much healthier people are if their thermal environment is NOT tightly controlled, as they did at Sue Roaf's 2022 Climate at the Extremes conference on Covid, Comfort and Ventilation. (www.comfortattheextremes.com).

What can we learn from the long history of the built environment in the way that it was operated as well as constructed, especially before and after the introduction of fossil fuel combustion?

What has changed, and why? There is so much to be learnt and understood from looking at that history, and it has every potential to make dramatic cuts quickly and without risk.

So, some big questions are: how do we derail the current juggernaut to doom? Will it require:

1. New messaging – based not least on a deep critique of current messaging?
2. Empowering people to be able to learn to 'sail their own buildings'?
3. Engaging the professions in a new way – getting them to question/ drop methodologies they don't even LIKE, but continue to use simply because they think everyone else is doing it…?
4. Looking at the whole timeline of a building – from past right into the future, including understanding change and failure – accepting once again that decay (and the need for maintenance) are baked in for ALL materials?
5. Starting to insist on knowledge of 'failure modes' to be a prerequisite before a material or assembly is used?

So many questions – so little time to make a difference - and going back to our first reflection – so little sense of urgency!

CONTRIBUTORS TO THE REFLECTIONS SECTIONS INCLUDED:

Paul Dorfman, Vanessa Gomes, David Jenkins, Daniel Overbey, Ulrike Passe, Andrew Peacock, Sue Roaf, Timothee de Toldi, Julio-Bros Williamson, Robyn Pender, Mina Jowkar and many more….

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