The 21^{st} Problem

Ensuring Security and Prosperity in a Rapidly Changing World

Summary

The Problem

- Catastrophic climate change is inevitable and irreversible [1] [2] [3]
- Our civilisation consistently underestimates the severity of the situation [4] [5] [6]
- It is likely that climate models have biases that prevent showing irreversible change [6] [7] [8]
- It is possible that a cascade of the Earth System toward a greenhouse state is underway [9] [10] [11] [12] {A1} {A2}
- Ancient climate records imply a potential for warming of 6-14°C [13] {A1}
- However our future may be without geological precedent in the last half a billion years [14]
- The threat is existential, unpredictable and developing at a rapid pace [15] [16] {A3} {A4}
- "Do The Maths" - this is an emergency, there is no time to wait for a cultural or economic shift toward sustainability [12] {A15} {A17}

The Solution

- We must utilise executive power to build infrastructure and implement laws to address the issue
- It is prudent to assume the worst and plan accordingly [2] [7] {A1} {A2} {A3} {A4} {A5} {A6} {A7}
- The root of the problem is a tight coupling between human activity and environmental conditions {A8} {A9} {A10} {A11} {A16}
- Separation of Concerns (SoC) between us and the environment is required to halt degradation and mitigate risk {A12} {A13} {A14} {A16}
- Vertical farming and advanced nuclear technologies offer viable long term solutions [17] [18] [19] [20] [21] [22] [23] {A13} {A14}
- As the nutrient loop is closed and electric infrastructure rolled out, hydrogen can become a primary energy carrier [26] [27] [28]
- Once SoC is achieved in all energy and bio production systems, the same design principles can be applied more broadly [29] {A12} {A16}
- SoC will ensure long-term prosperity for the human race and provide the global stability required to begin restoration [30] [31] [32] {A18}
- Though potentially a 10,000+ year project, returning the Earth System to an optimal state for humanity is a realistic goal [33] [34] [35] [36]

{References}

Appendix 1 - CO2, Forcing & Temperature

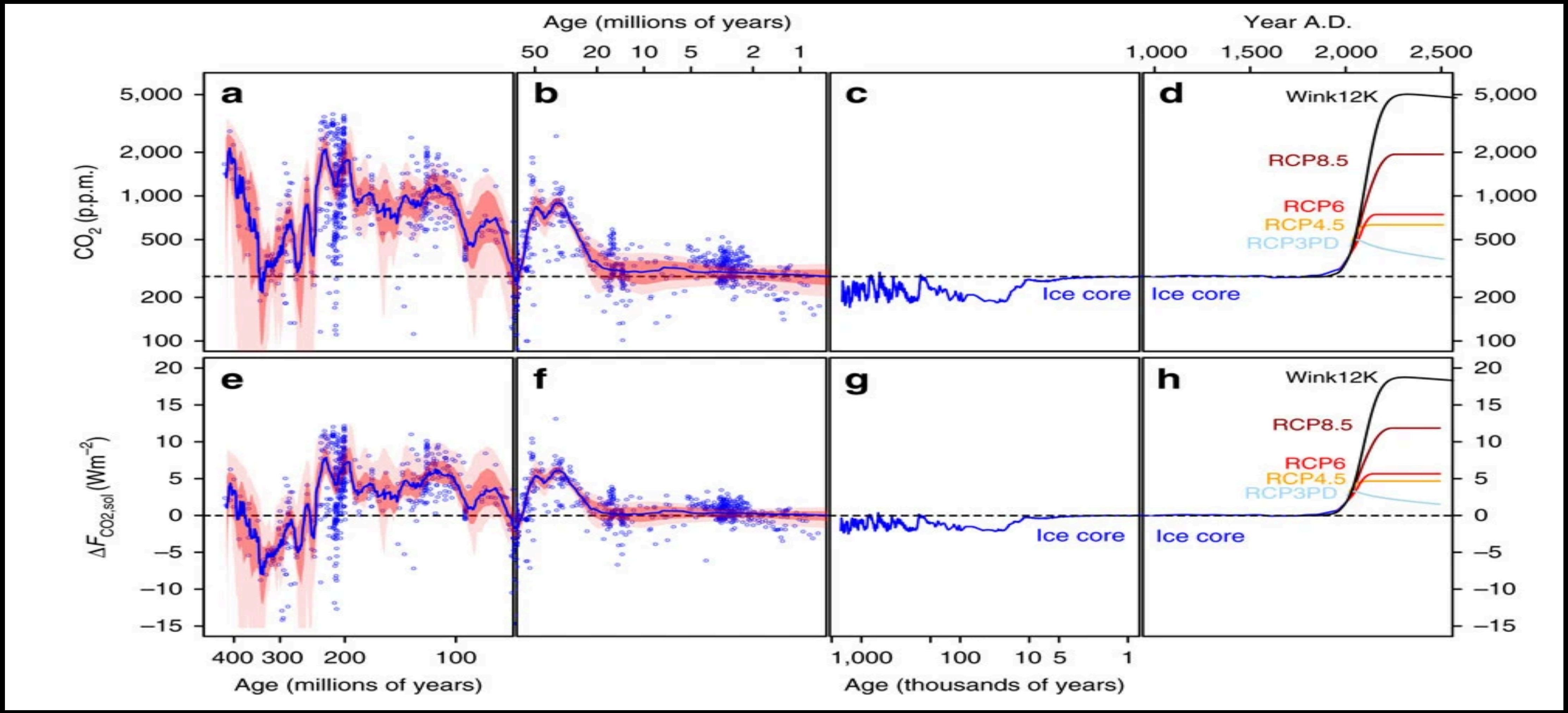


Fig. 1 - Temporal evolution of CO2 and climate forcing [14]

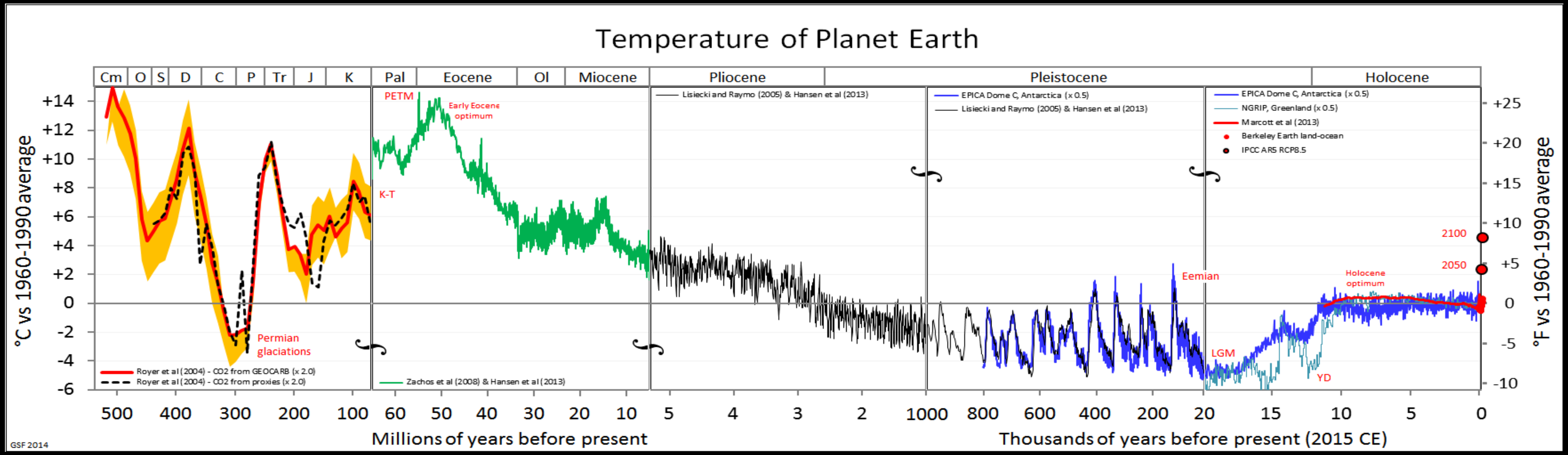


Fig. 2 - Global average temperature estimates for the last 540My by Glen Fergus - Wikimedia Commons

{Summary} {References}

Appendix 2 - Cascade Illustrations

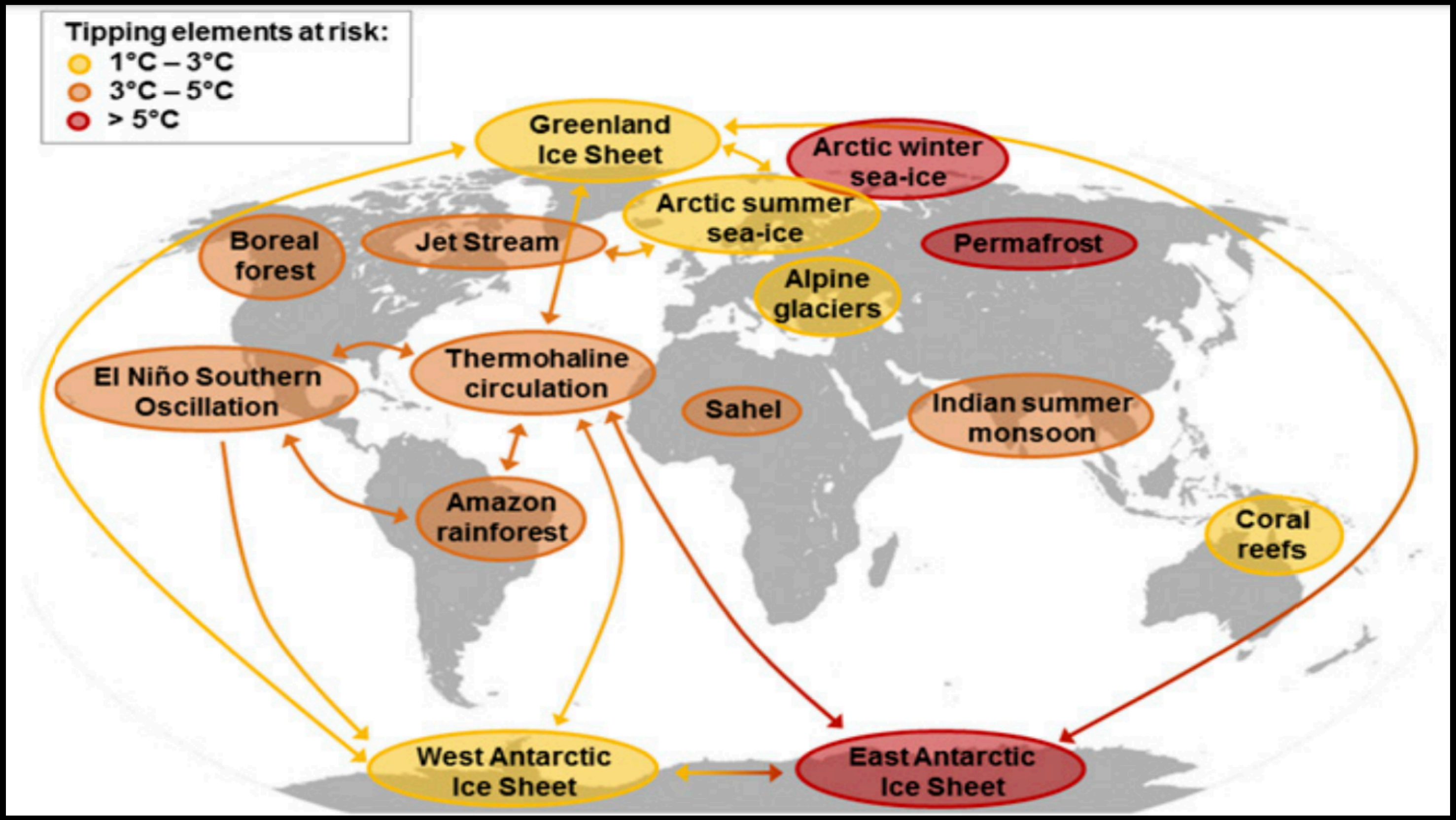


Fig. 3 - Global map of potential tipping cascades. The individual tipping elements are colour coded according to estimated thresholds in global average surface temperature. Arrows show the potential interactions among the tipping elements based on expert elicitation that could generate cascades [9]

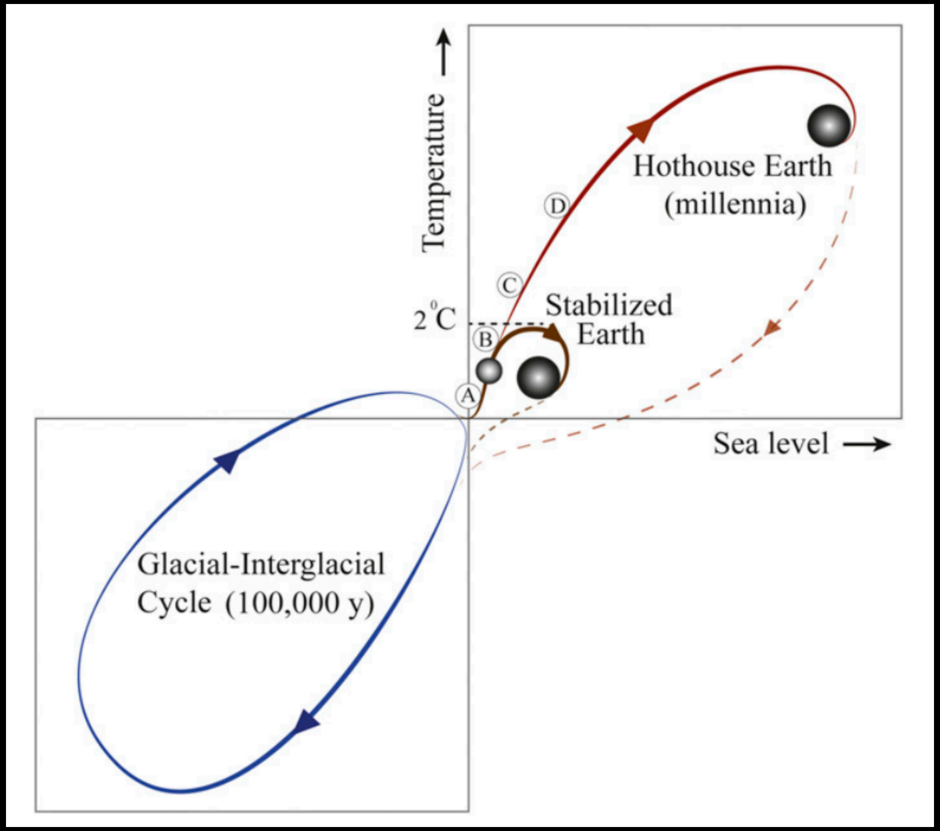


Fig. 4 - A schematic illustration of possible future pathways of the climate against the background of the typical glacial-interglacial cycles. The horizontal line in the middle of the figure represents the preindustrial temperature level, and the current position of the Earth System is shown by the small sphere on the red line close to the divergence between the Stabilised Earth and Hothouse Earth pathways. A = Mid-Holocene, B = Eemian, C = Mid-Pliocene and D =Mid-Miocene [9]

Appendix 3 - Emissions & Masking

Fig. 5

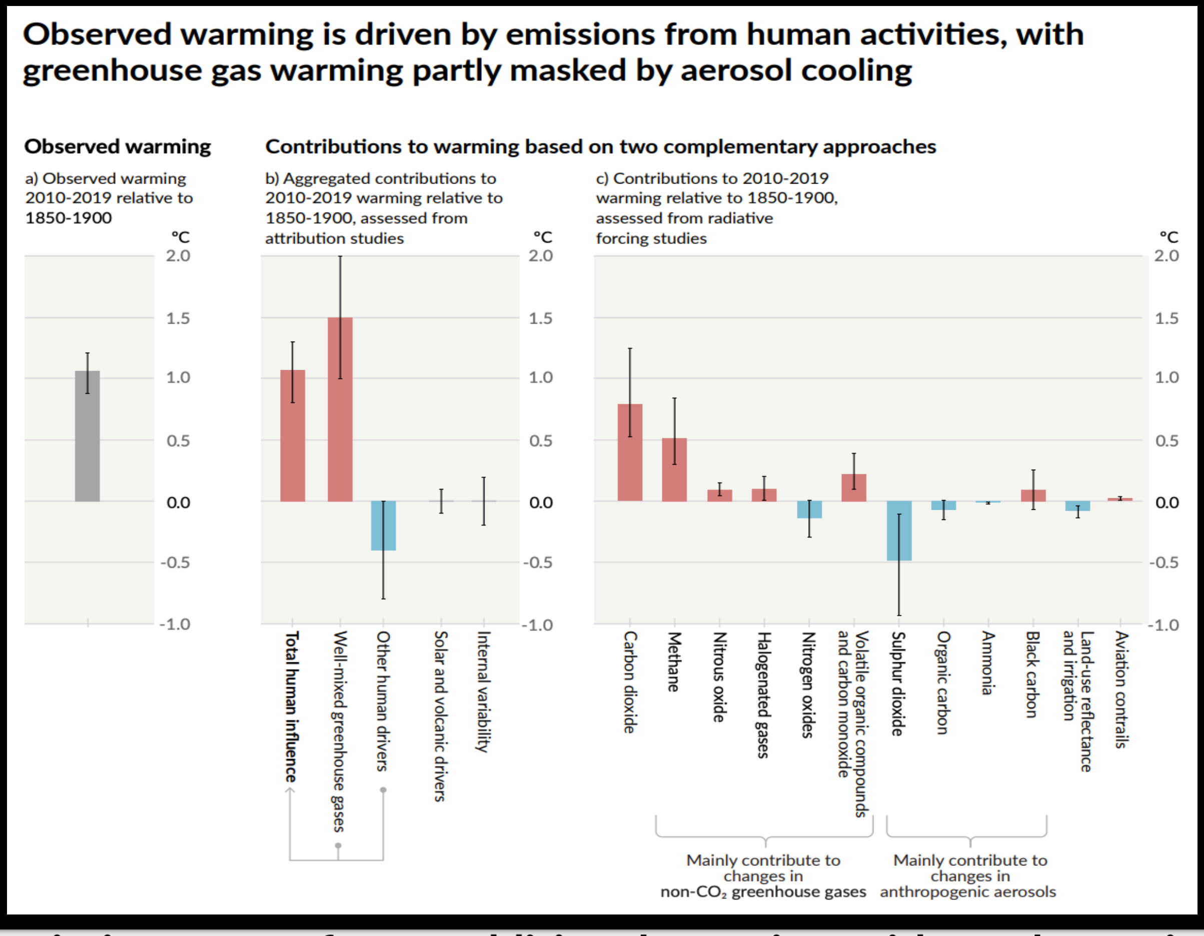
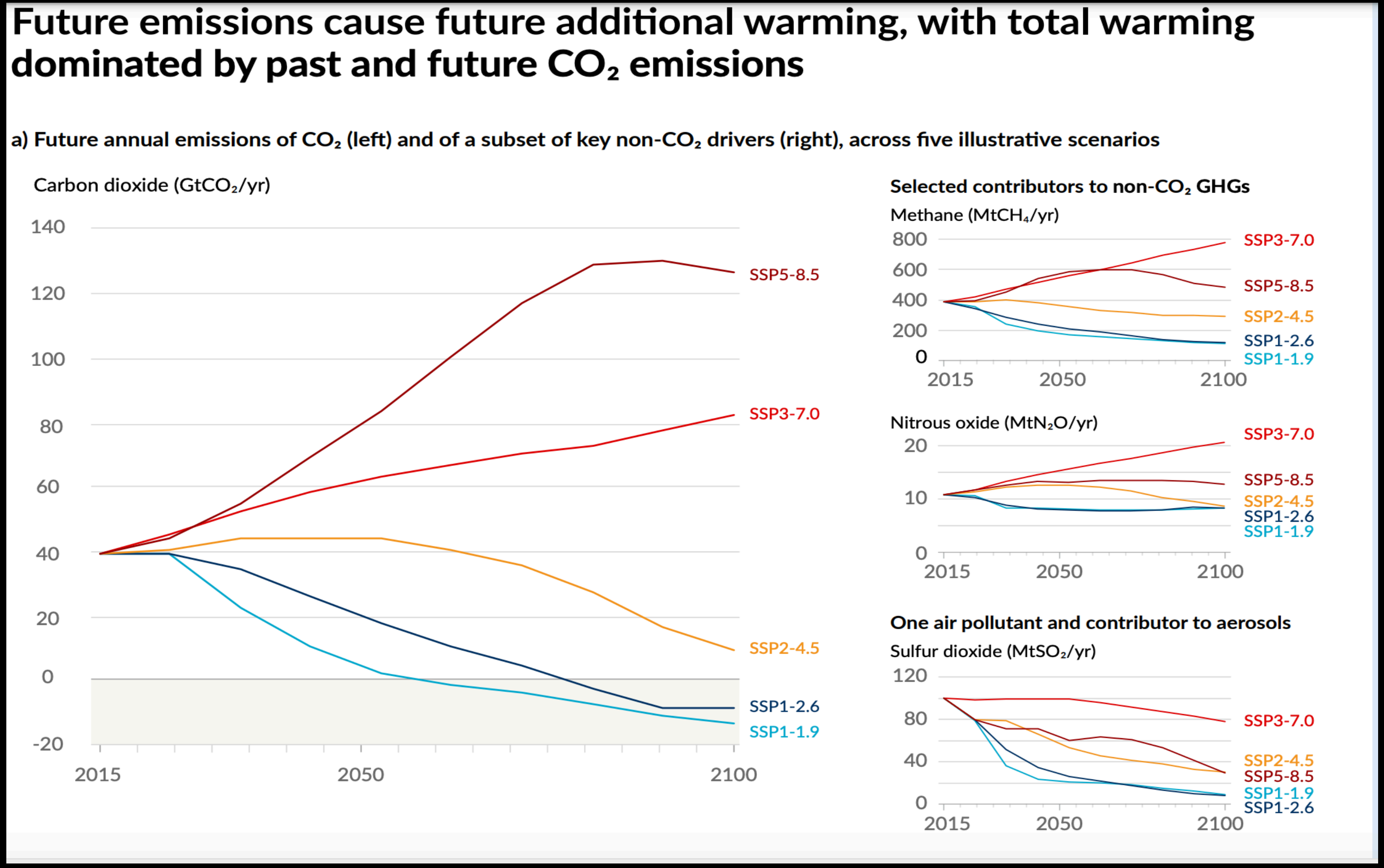


Fig. 6



IPCC, 2021 [2]

Appendix 4 - Effects 1

Fig. 7

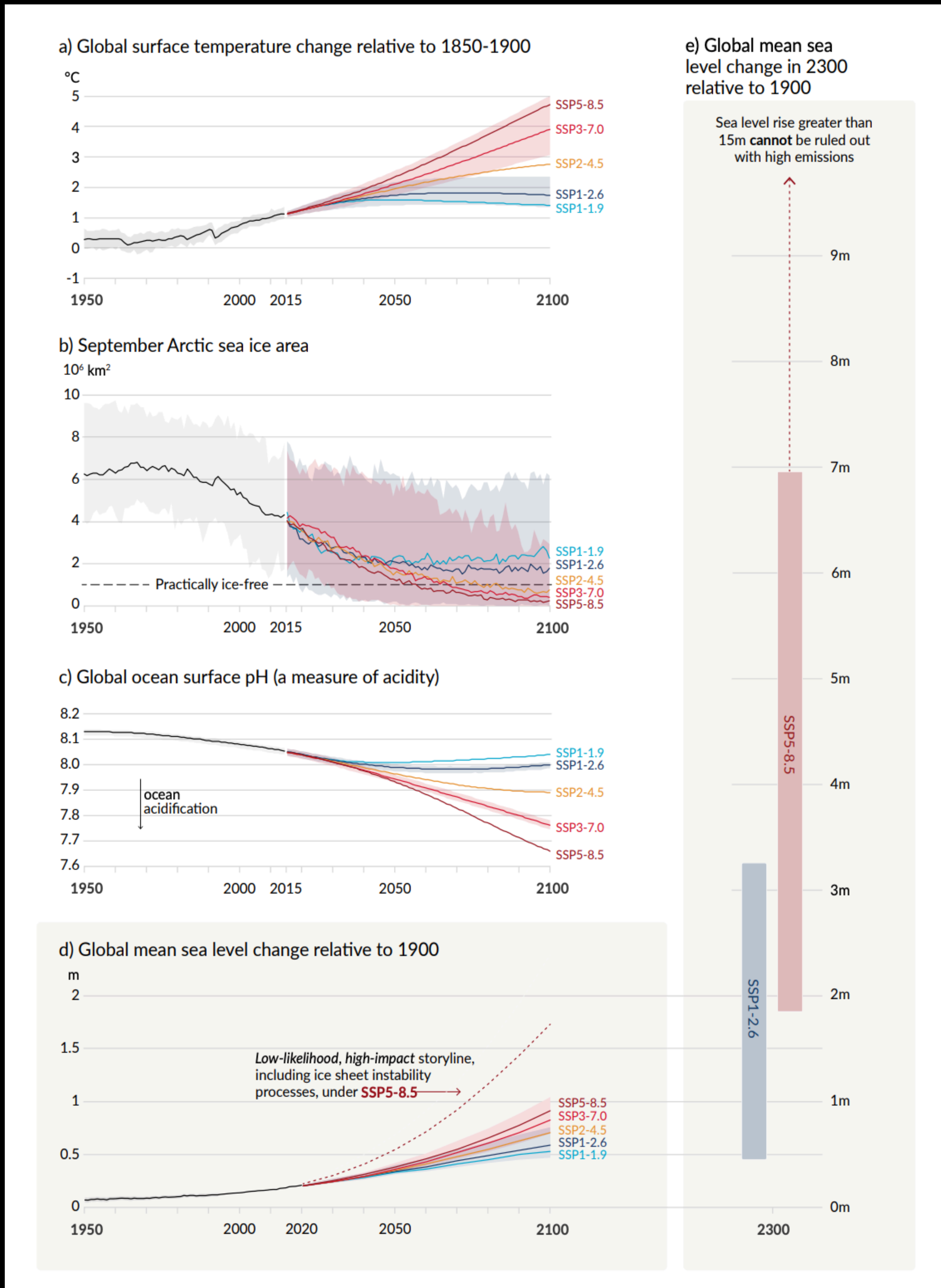
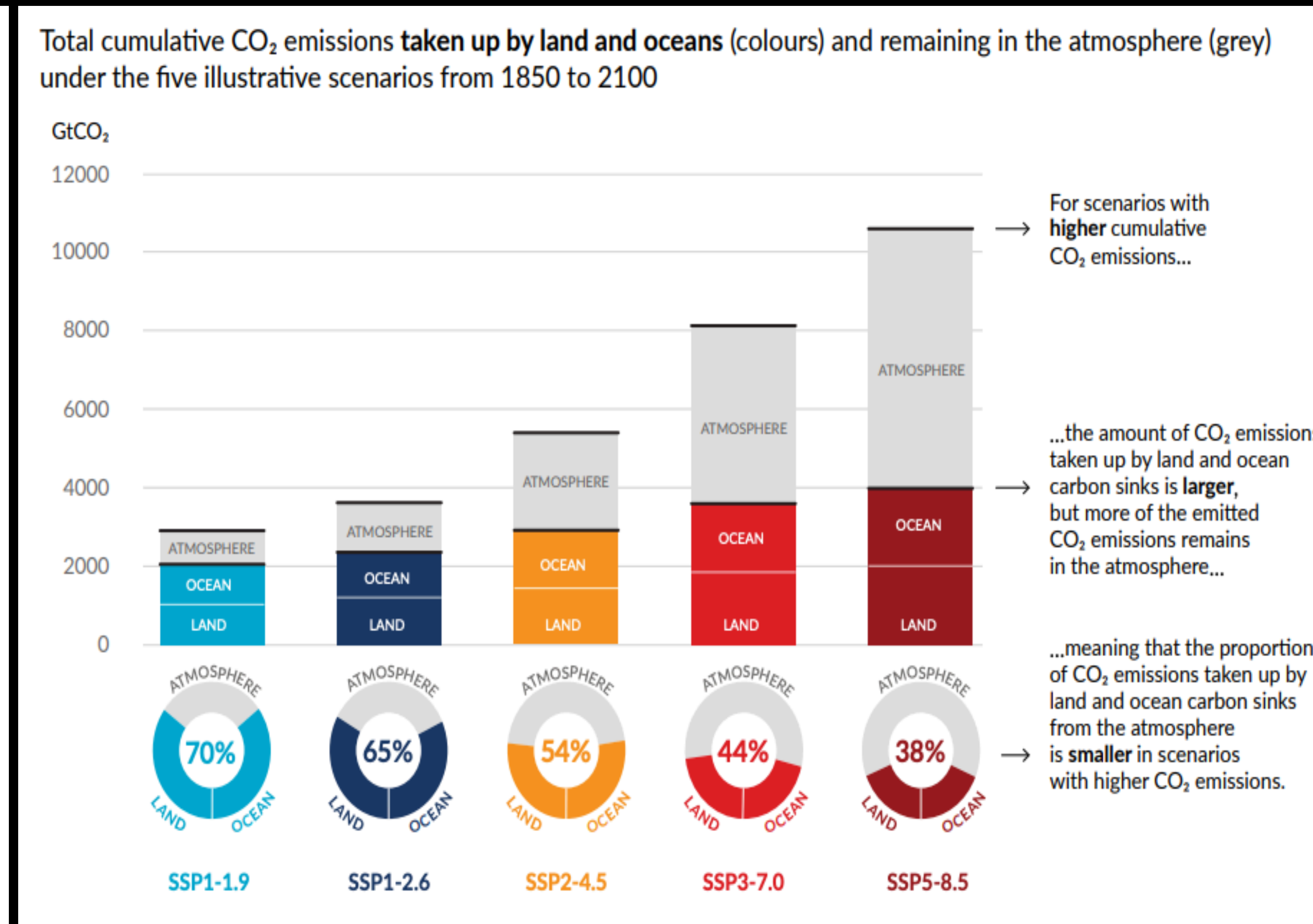
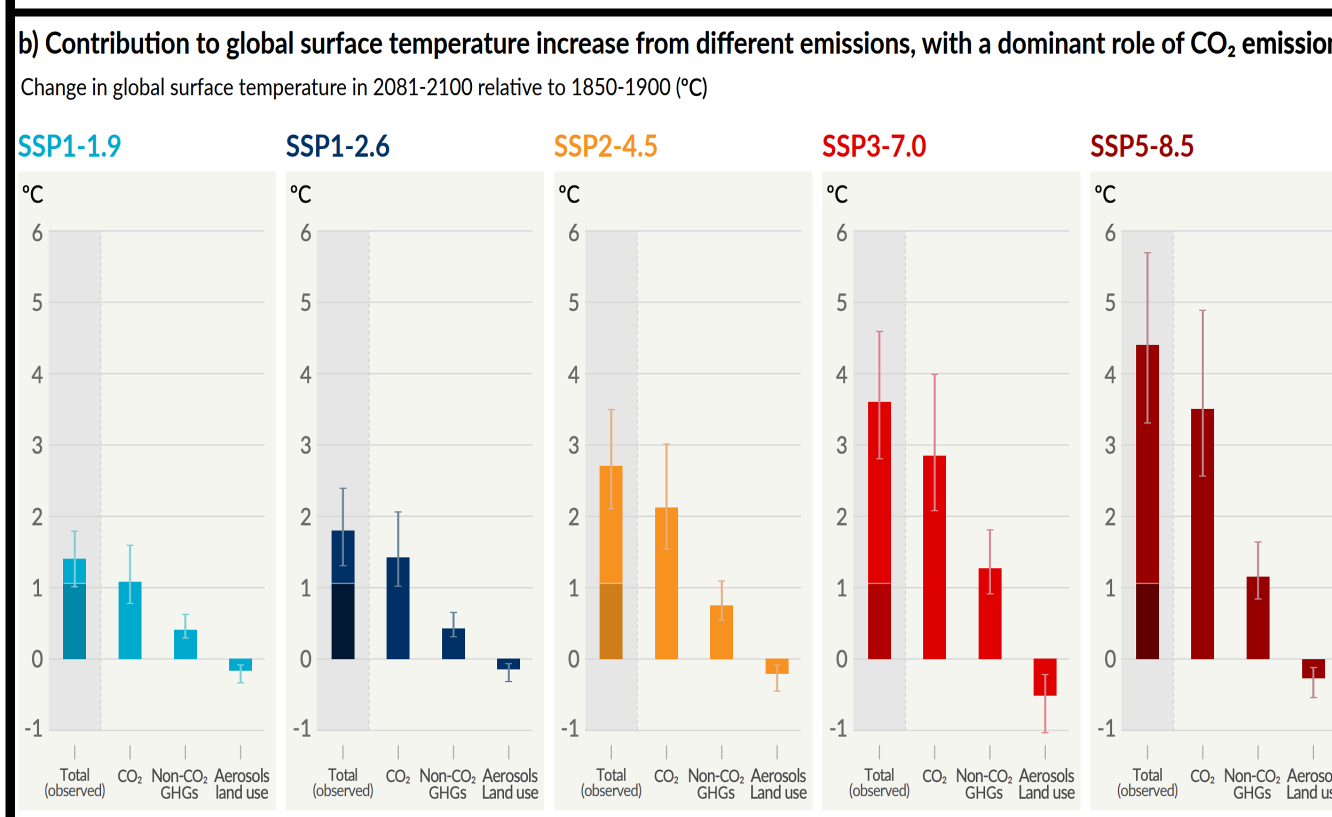


Fig. 8





IPCC, 2021 [2]

Fig. 9

{Summary}

{References}

Appendix 5 - Effects 2

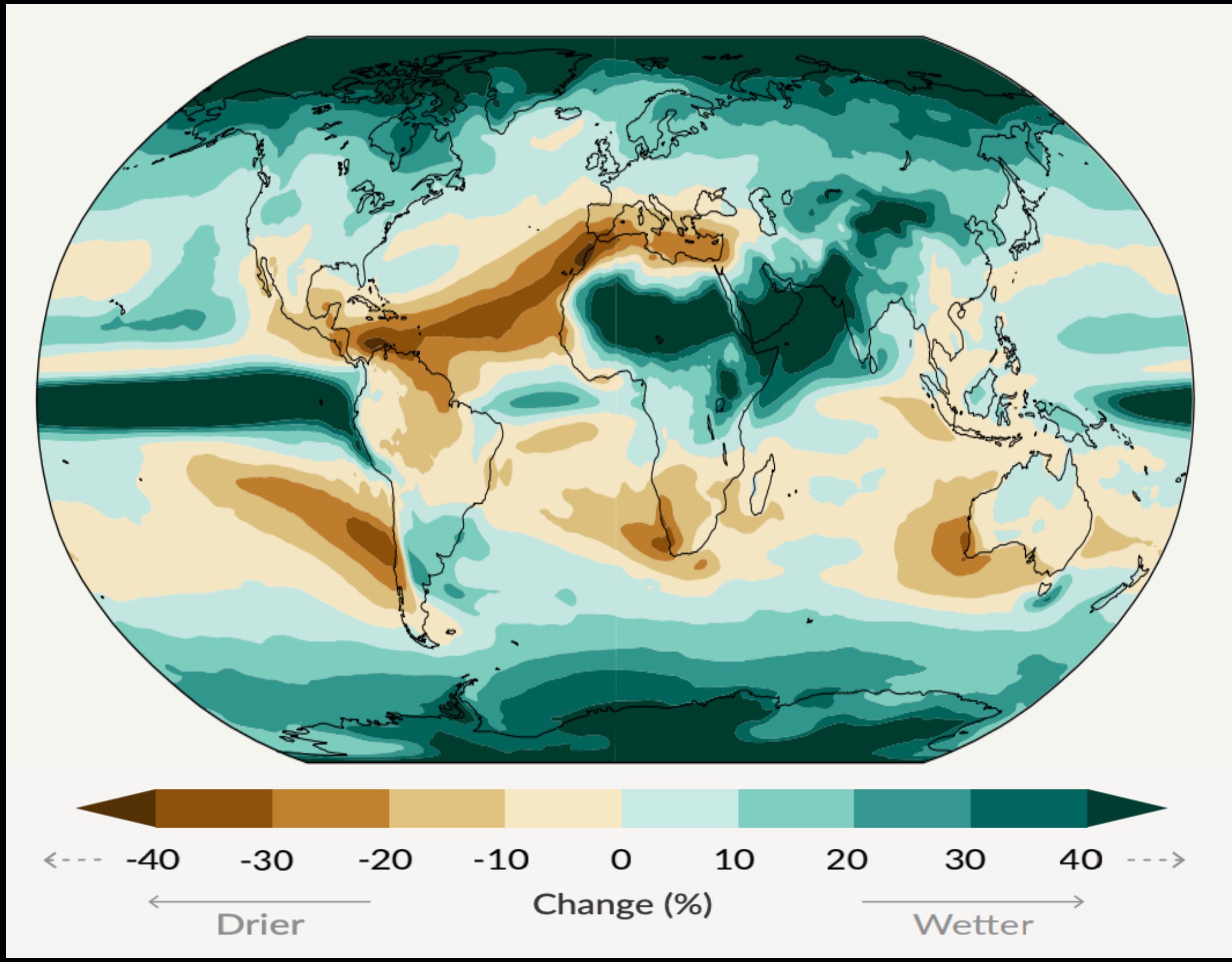


Fig. 10 - Simulated Annual Mean Precipitation Change (%) at 4°C Global Warming Relative to 1850-1900 [2]

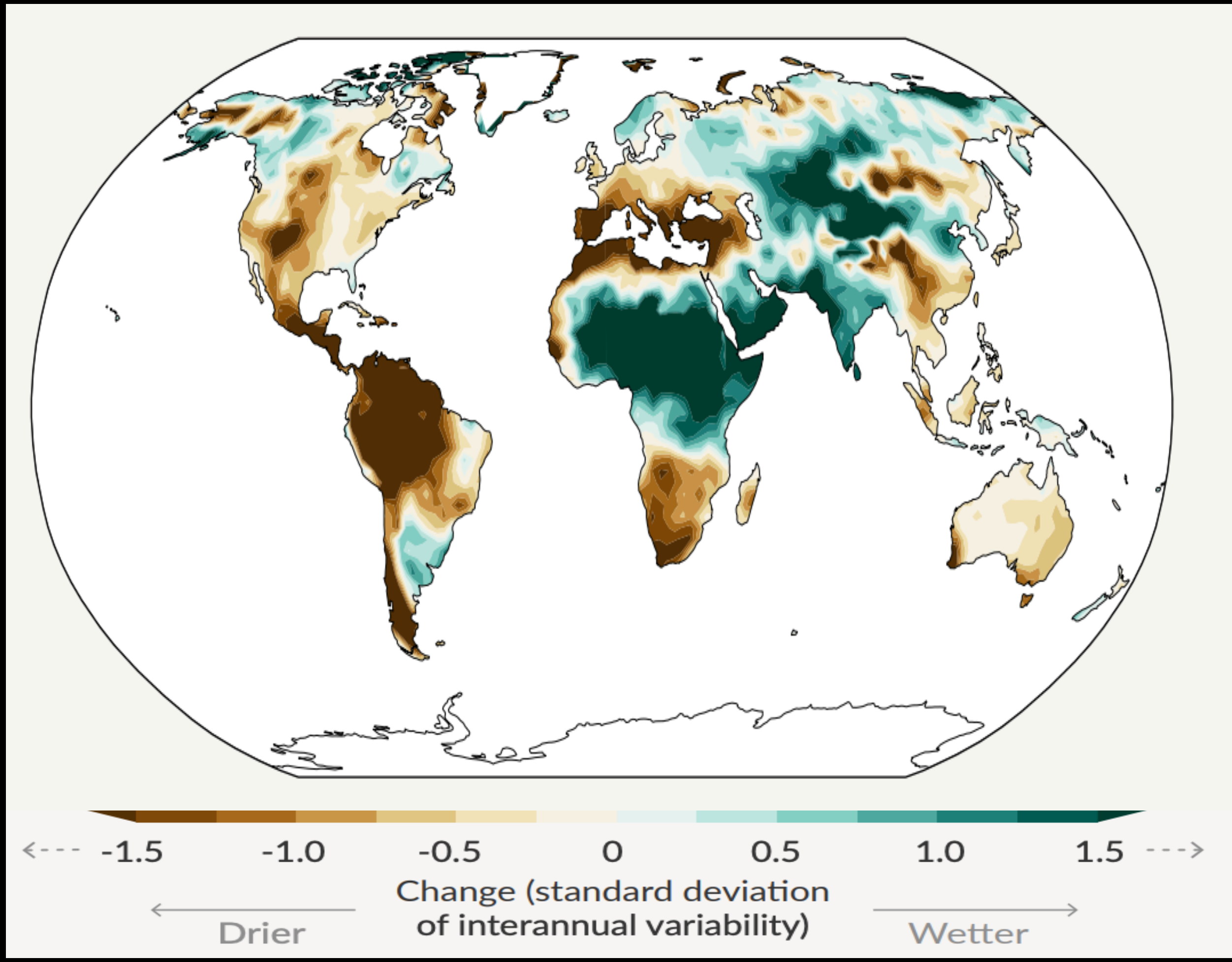


Fig. 11 - Simulated Annual Mean Total Column Soil Moisture Change (Standard dev) at 4°C Global Warming Relative to 1850-1900 [2]

Appendix 6 - Effects 3

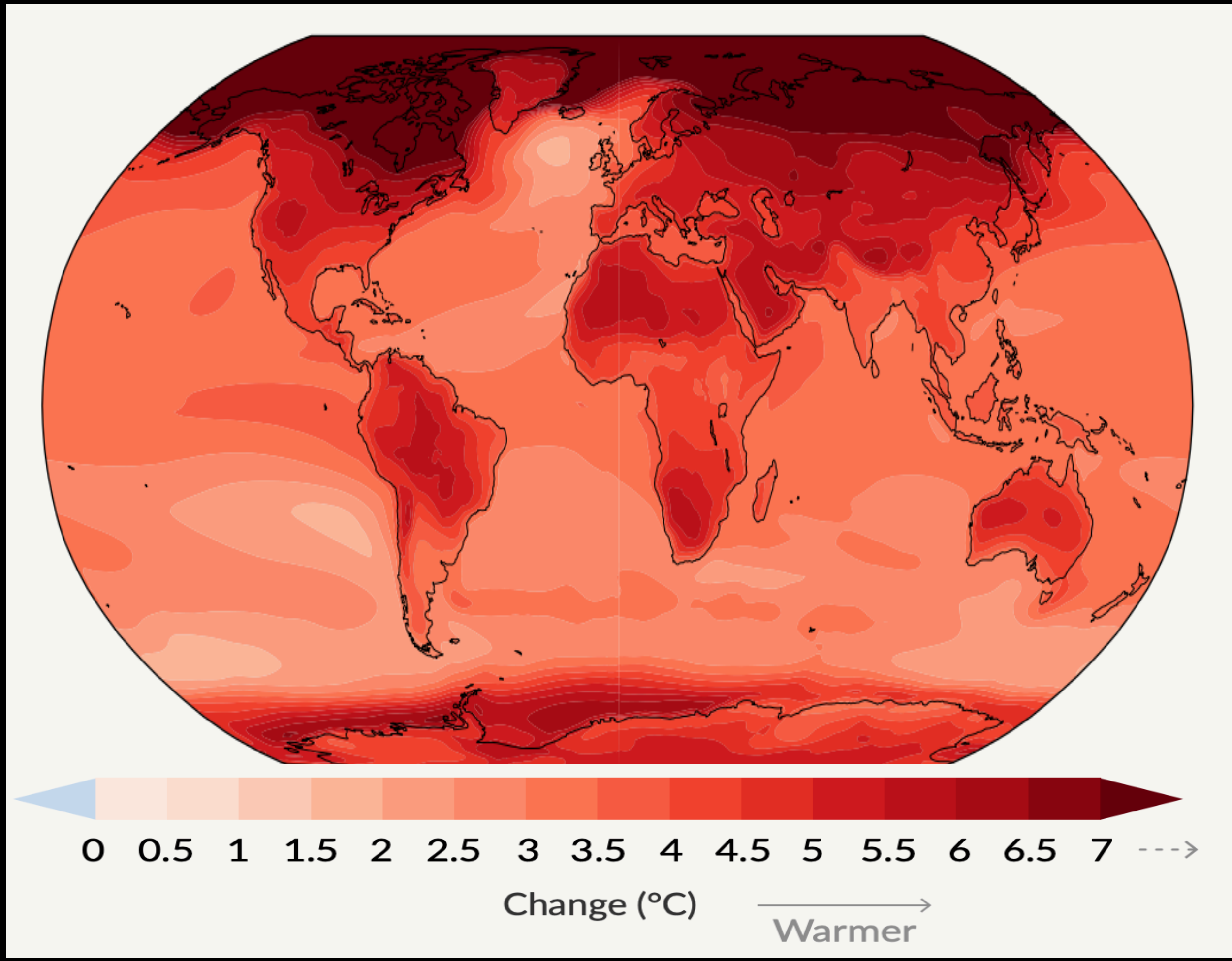


Fig. 12 - Simulated Annual Mean Temperature Change at 4°C Global Warming Relative to 1850-1900 [2]

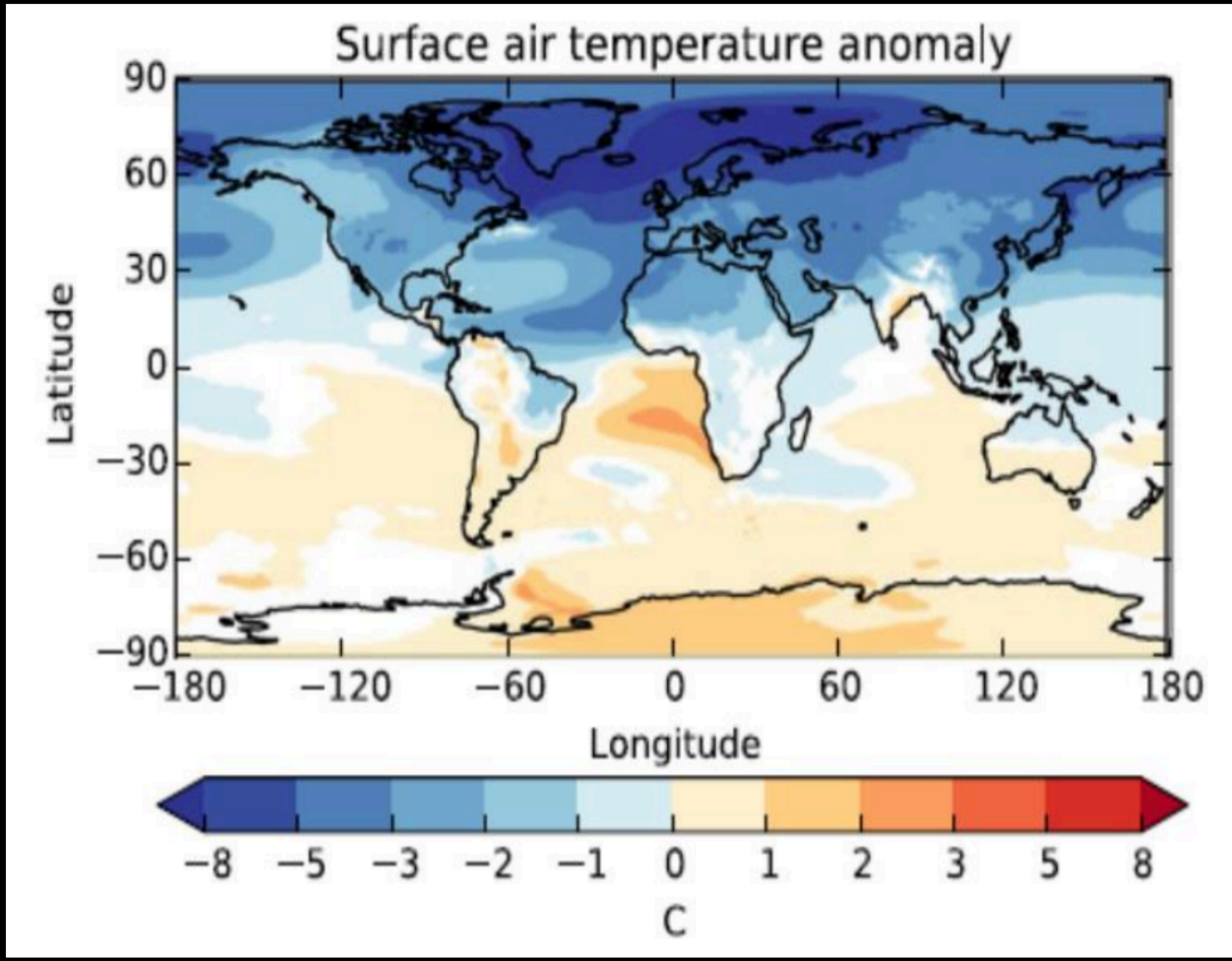


Fig. 13 - Projected Surface Air-temp Change with Collapse of AMOC [7]

Fig. 14

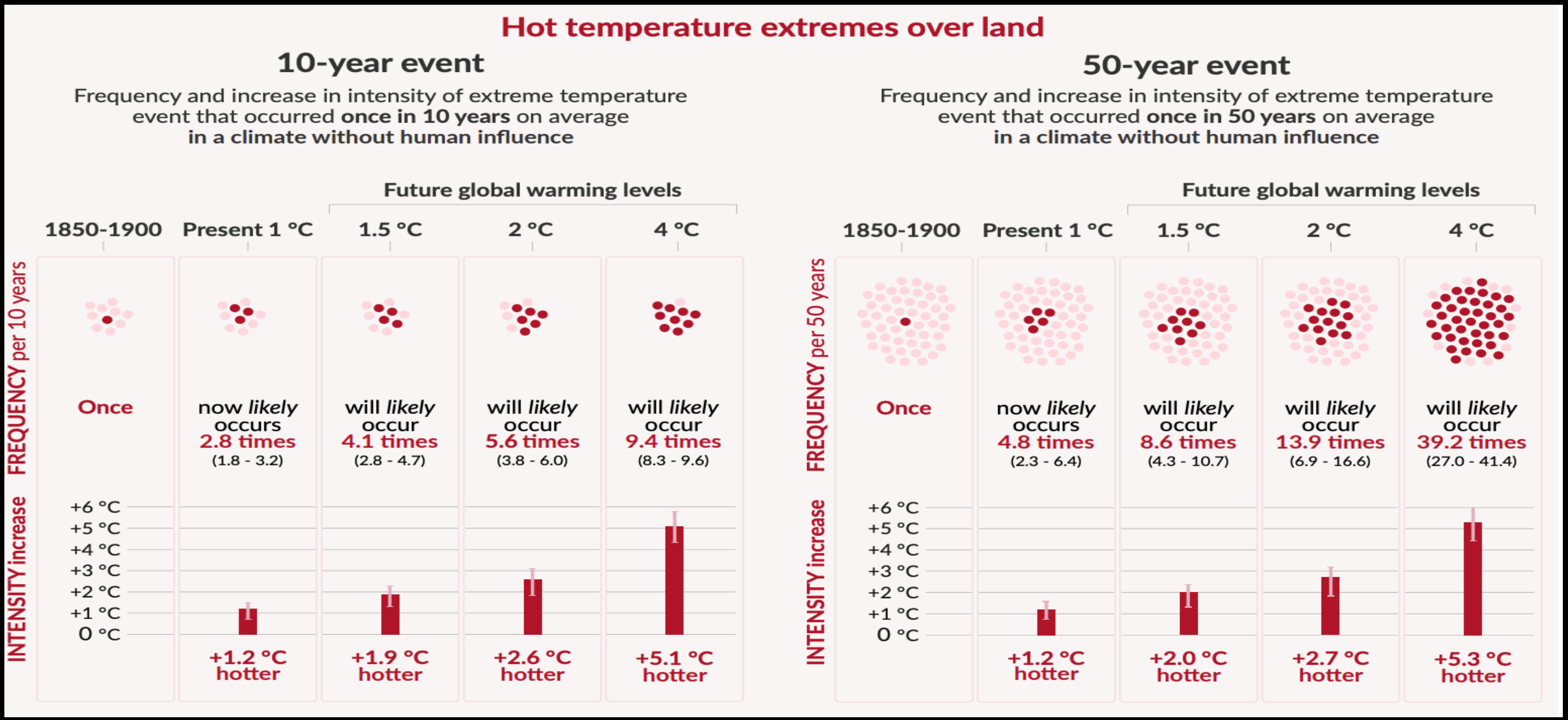
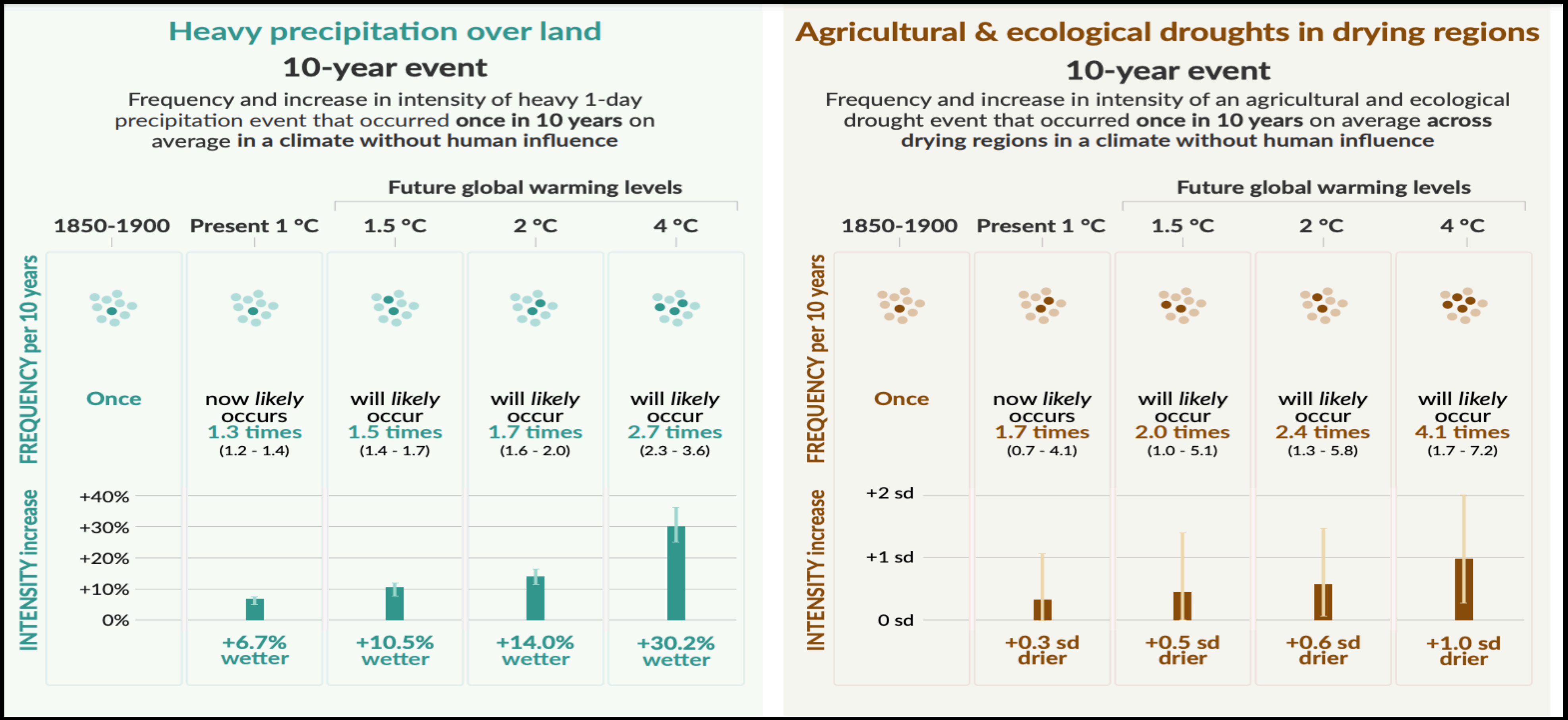


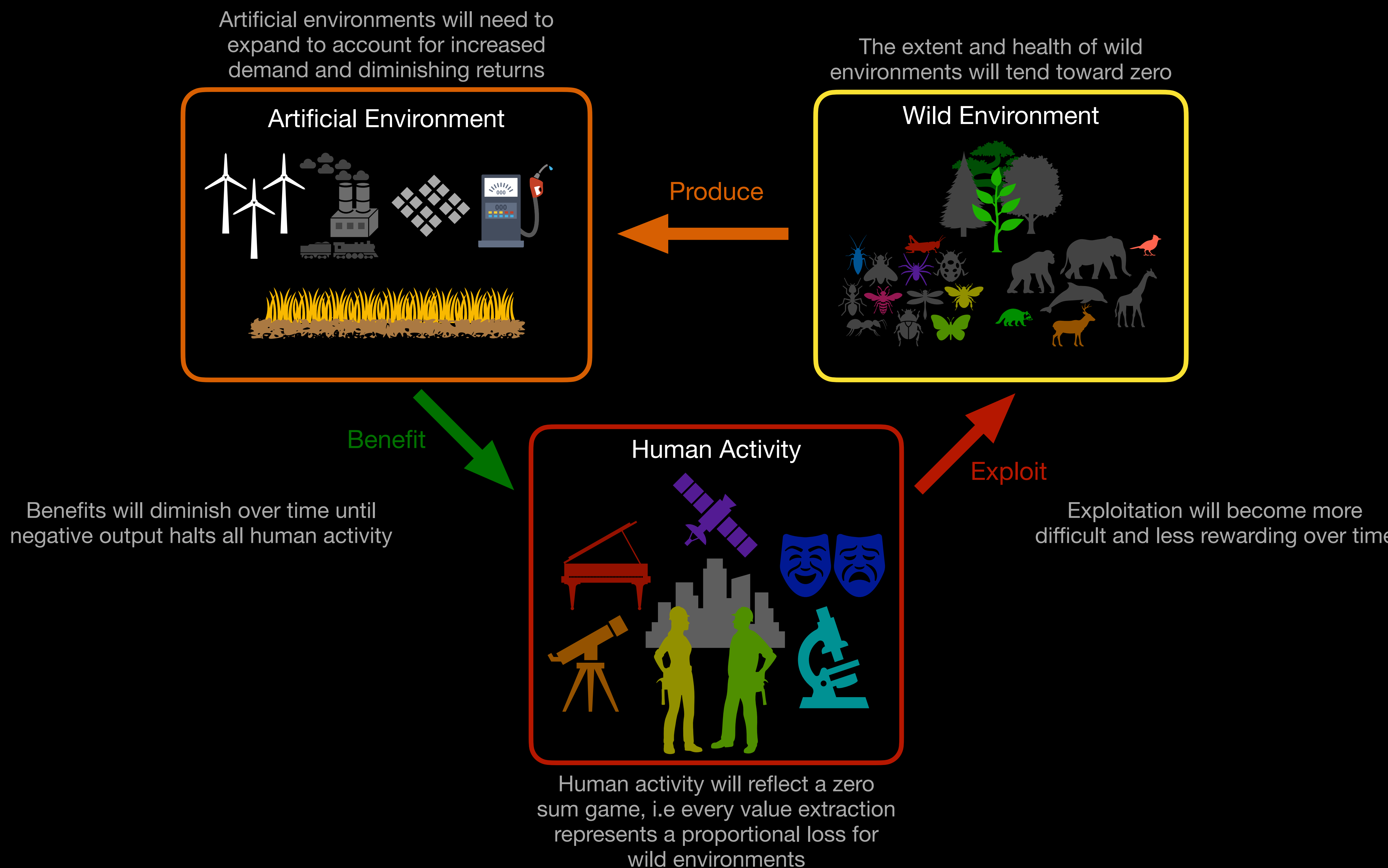
Fig. 15



 IPCC, 2021 [2]

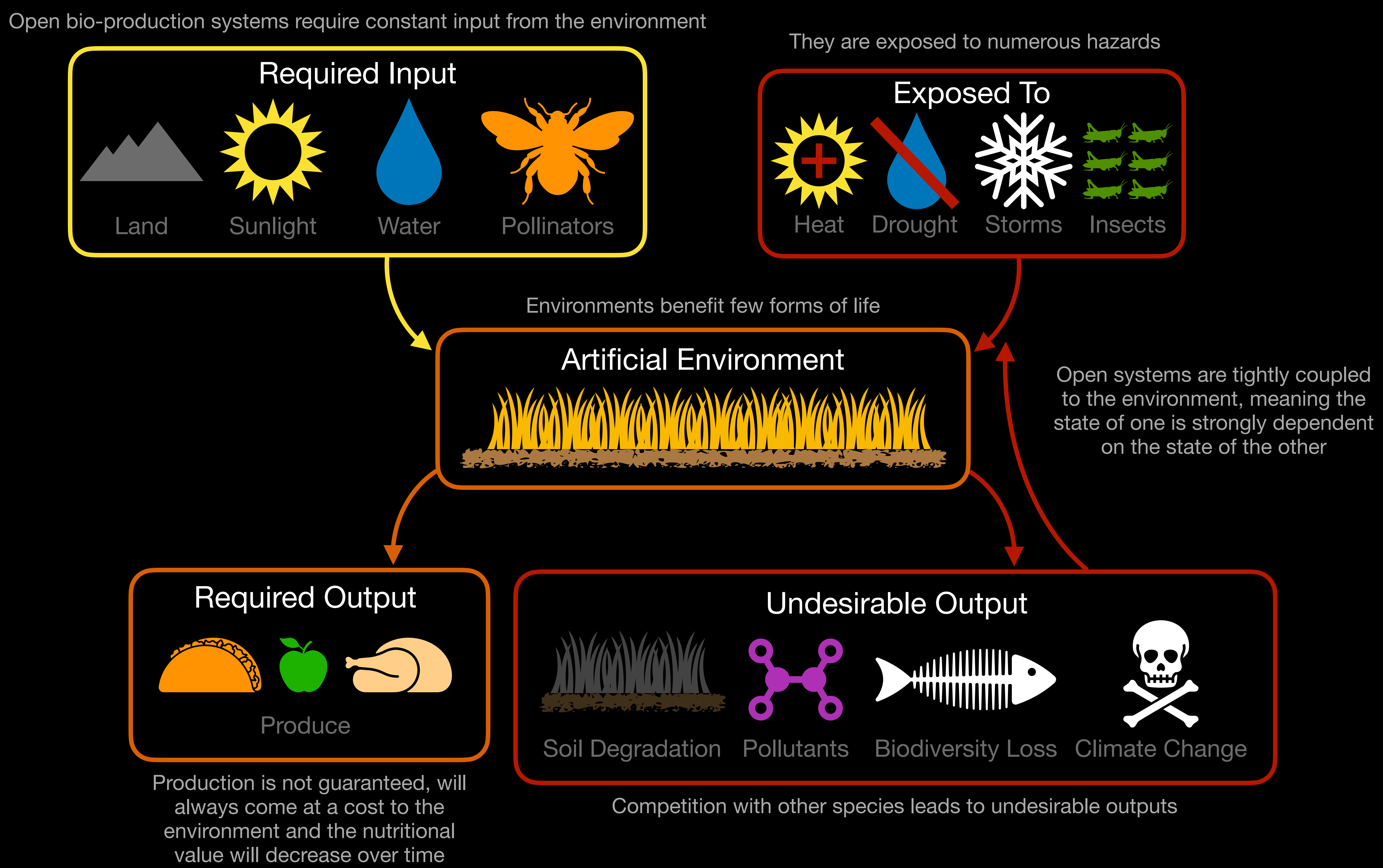
Appendix 8 - Design Principles - Open Systems

Open systems require constant input from, and will degrade, wild environments. They are exposed to environmental conditions, meaning hazardous in/output pose a serious risk. These systems display a two-way dependency between human and environmental health



{Summary} {Closed Systems} {SoC} {References}

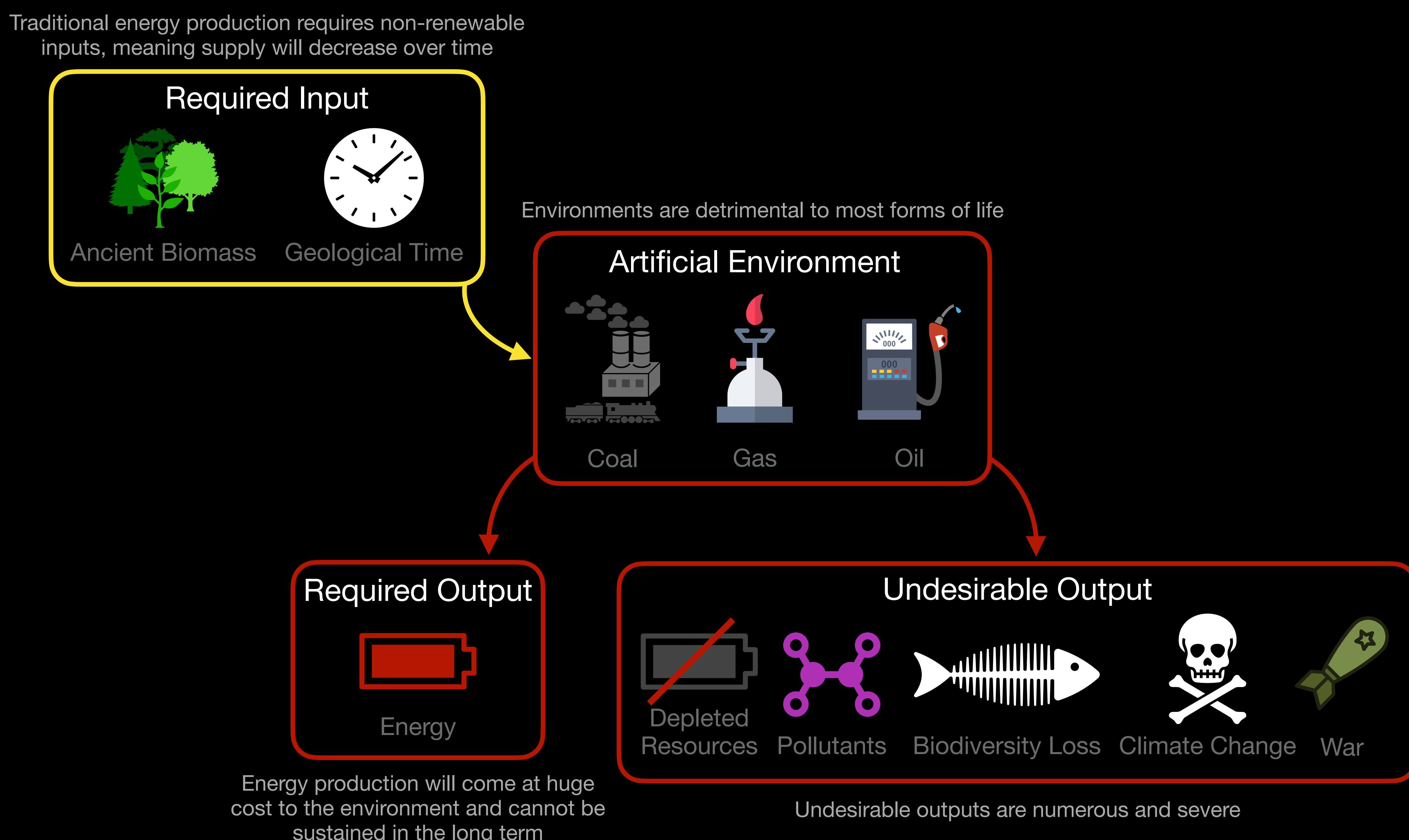
Appendix 9 - Open Production Systems - Traditional Bio



{Summary}

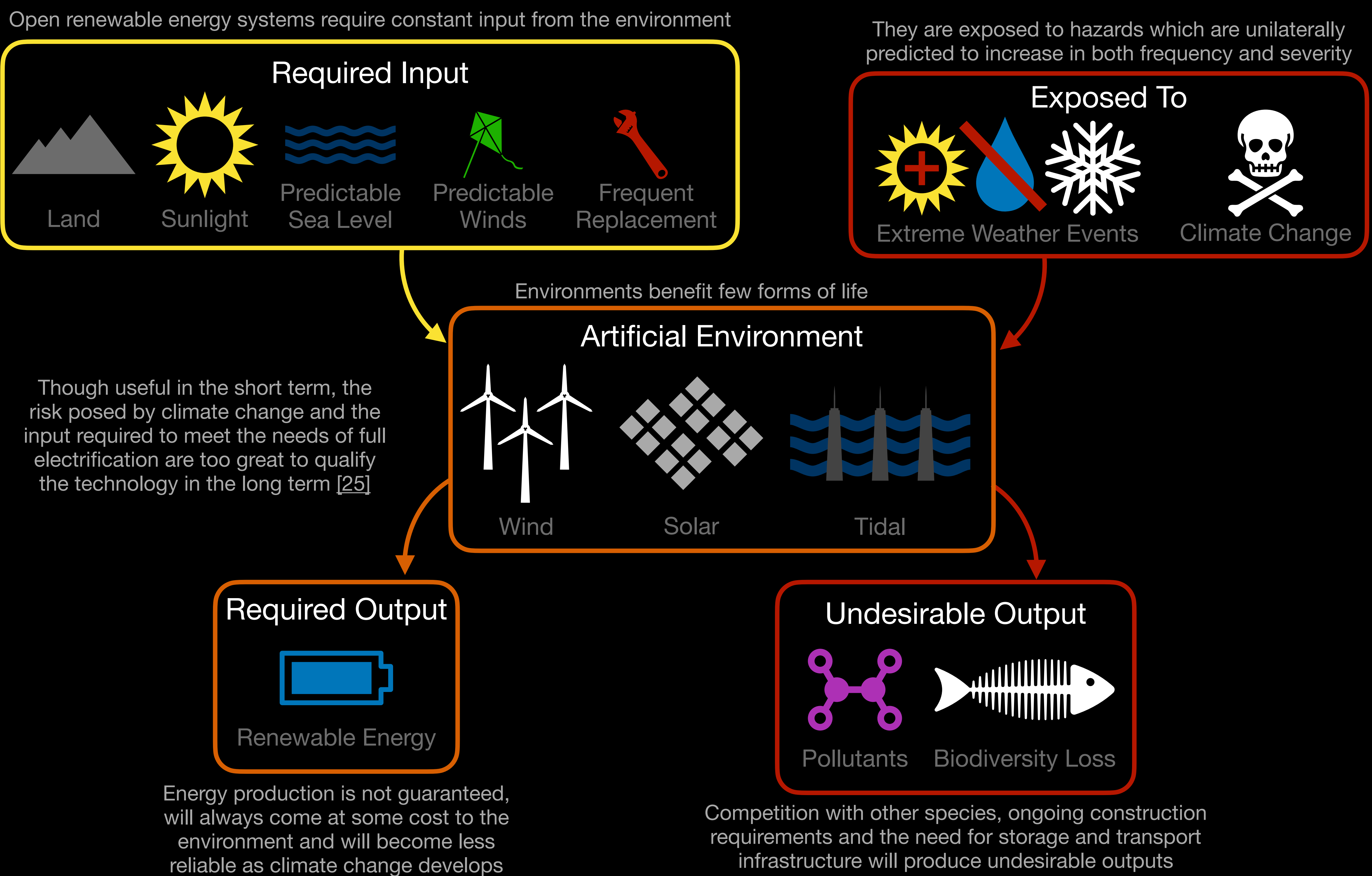
{References}

Appendix 10 - Open Production Systems - Traditional Energy



{Summary}
{References}

Appendix 11 - Open Production Systems - Renewable Energy



{Summary}

{References}

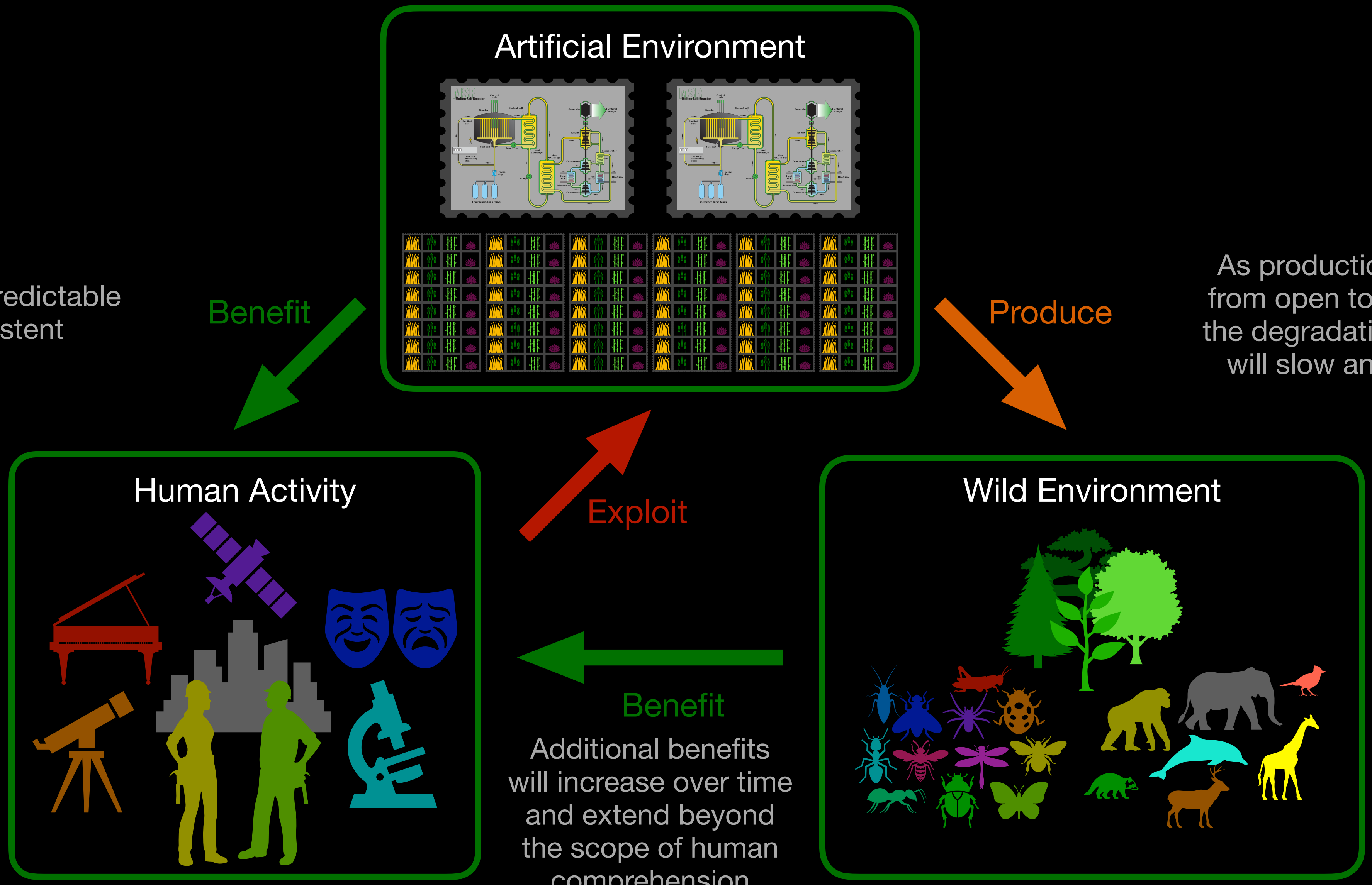
Appendix 12 - Design Principles - Closed Systems

Closed systems require artificial input only and are inherently insulated from environmental conditions, meaning hazardous in/output are negated by design. This severs the two-way dependency of human and environmental health

Artificial environments can be contained to populated areas and will not directly effect the state of wild environments

Outputs are predictable and consistent

As production systems transition from open to closed architectures, the degradation of the environment will slow and eventually reverse



Human activity will reflect a fractal algorithm, i.e with each iteration all systems grow in size and complexity

The extent and health of wild environments will increase over time, potentially overtaking that at any point in Earth's history

{Summary} {Open Systems} {SoC} {References}

Appendix 13 - Closed Production Systems - Advanced Bio

Closed systems require artificial input only

Required Input

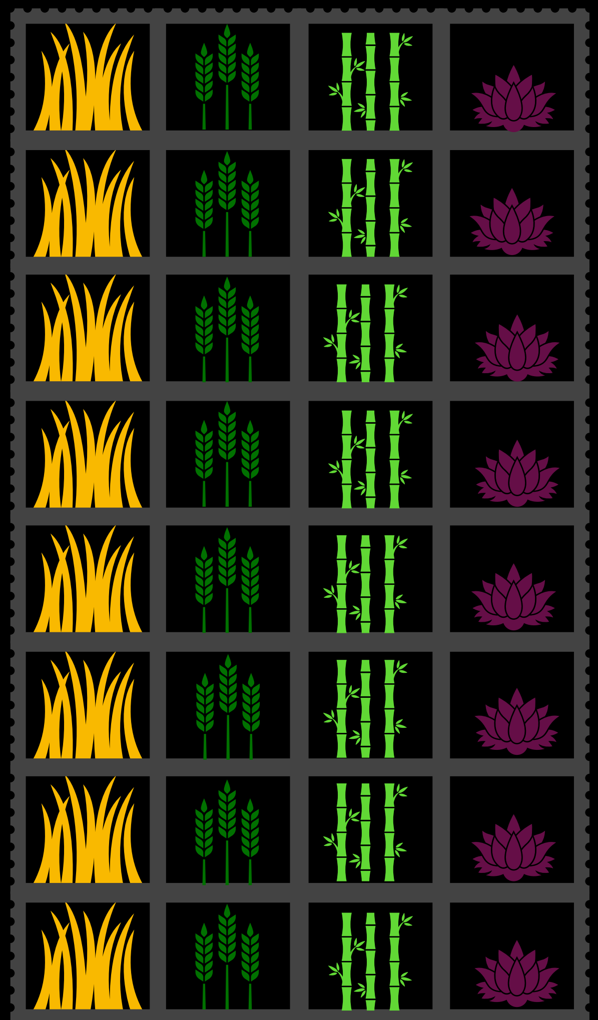
Nutrients | Recycled Water | Clean Energy

Closed systems are loosely coupled to the environment, meaning the state of one will rarely effect the state of the other

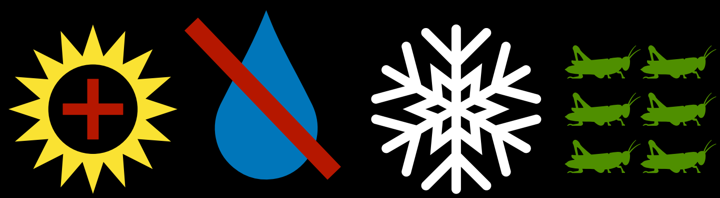
However because our footprint is so large, construction of such systems will be of huge benefit to the environment

Environments can benefit all forms of life [24] and are inherently shielded from hazards

Artificial Environment



Protected From



Heat | Drought | Storms | Insects

Vertical architecture requires a fraction of the land used by traditional farming methods and can be built where bio-products are consumed, removing the need for preservation and transport [22]

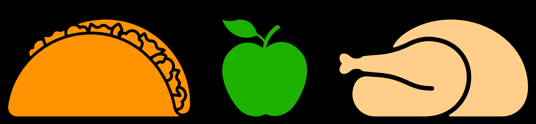
Inherent protection from competitive species means no insecticides are required [23]

Use of aeroponics ensures no soil degradation, no loss of nutritional value and reduces water usage by 95% [23]

Removing dependence on the Sun allows for artificial growth cycles, massively increasing yield / m³ and allowing for crops of any continent to be grown locally [23]

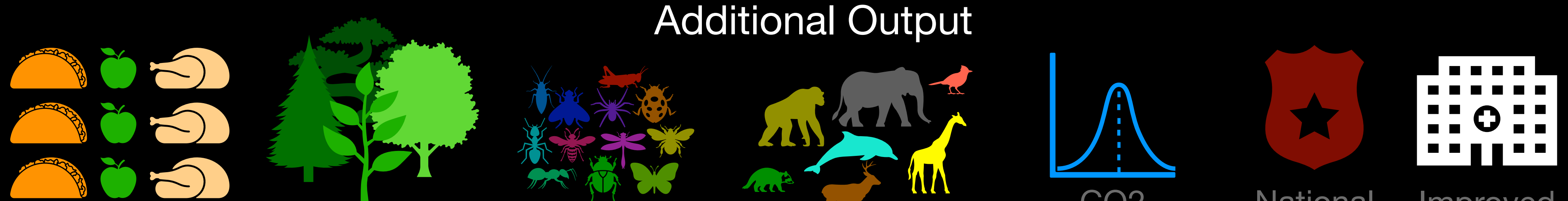
Production is guaranteed, impact on the environment is minimal and the nutritional value is consistent

Required Output



Produce

Additional Output



More Produce | Rewilding | More Insects | Biodiversity Gain | CO2 Sequestration | National Security | Improved Health

Additional outputs are numerous and benefit all nations and all species, irrespective of who deploys the system

{Summary} {References}

Appendix 14 - Closed Production Systems - Advanced Nuclear Energy

Nuclear produces one of the smallest carbon footprints of all energy sources [17]

Modern reactors are passively safe, meaning there is no risk of a meltdown. This enables small, modular reactors to be built closer to where the energy is needed [18]

A closed fuel cycle with breeders can minimise the waste produced, and what remains can be stored safely [19]

Proliferation aside, nuclear is as safe as any renewable, and is more durable, reliable and productive [20]

Nuclear is capable of providing a reliable source of clean energy, independent from the state of the Earth, for 4 billion years [21]

Closed systems require artificial input only

Required Input

Nuclear Fuel

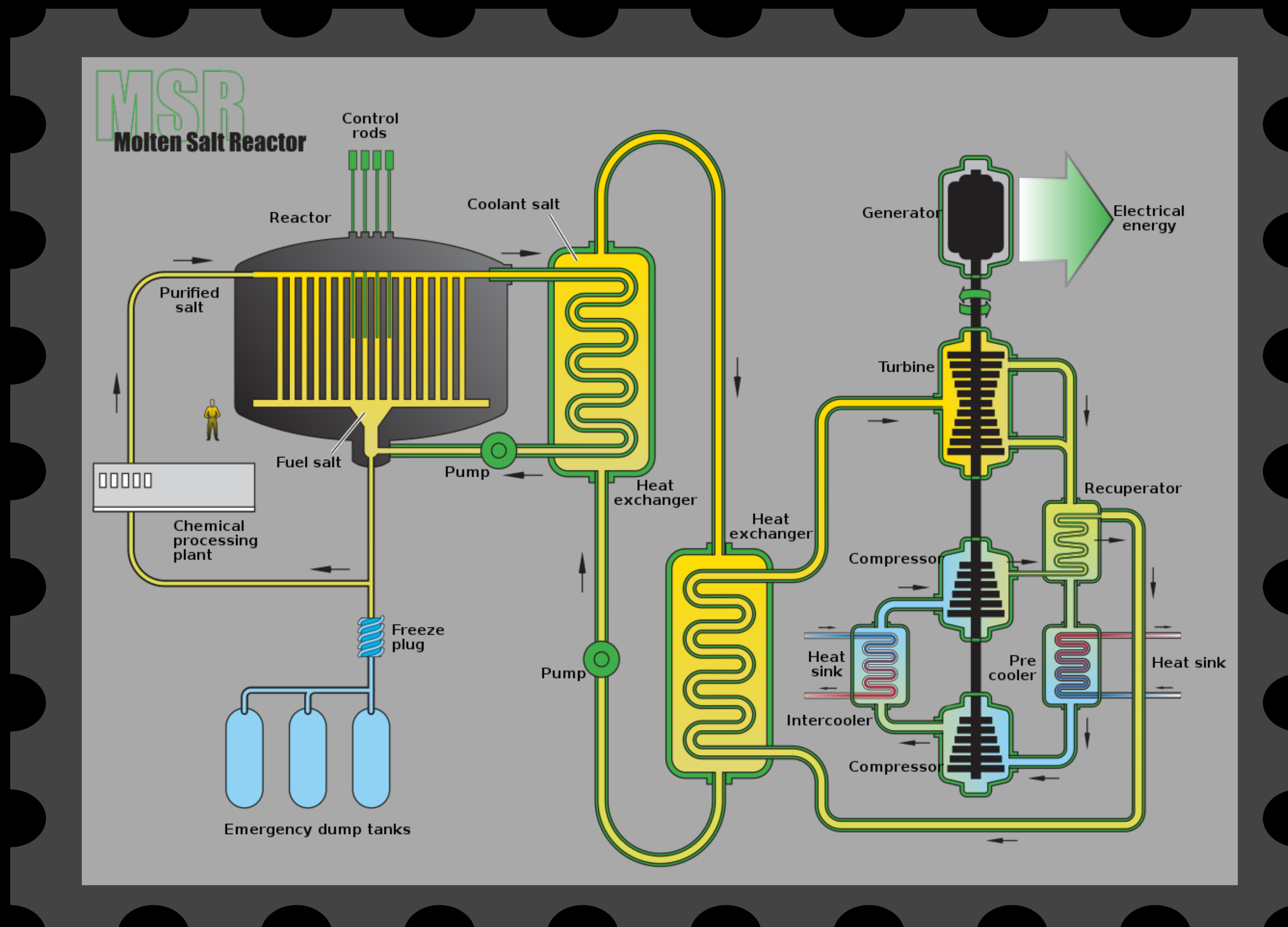
They are inherently shielded from hazards

Protected From

Extreme Weather Events

Climate Change

Artificial Environment



Required Output

Clean Energy

Energy production is reliable and impact on the environment is minimal. Energy production will remain reliable as the effects of climate change become more pronounced

Additional Output

More Energy

National Security

Undesirable Risk

Nuclear Weapons

Increased nuclear proliferation improves the chance of a rogue element developing a nuclear weapon. Strong international oversight would be required to mitigate this risk. However for nations with access to nuclear technology, constructing such systems would not pose a significant additional risk

{Summary}

{References}

EMERGENCY: DO THE MATHS

We define emergency (E) as the product of risk and urgency. Risk (R) is defined by insurers as probability (p) multiplied by damage (D). Urgency (U) is defined in emergency situations as reaction time to an alert (τ) divided by the intervention time left to avoid a bad outcome (T). Thus:

$$E = R \times U = p \times D \times \tau / T$$

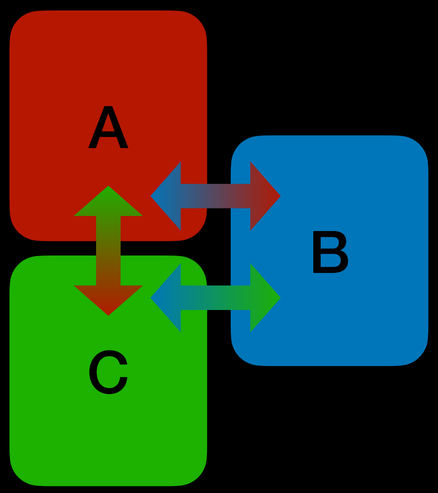
The situation is an emergency if both risk and urgency are high. If reaction time is longer than the intervention time left ($\tau / T > 1$), we have lost control.

"We argue that the intervention time left to prevent tipping could already have shrunk towards zero, whereas the reaction time to achieve net zero emissions is 30 years at best. Hence we might already have lost control of whether tipping happens. A saving grace is that the rate at which damage accumulates from tipping - and hence the risk posed - could still be under control to some extent. The stability and resilience of our planet is in peril. International action - not just words - must reflect this" [12]

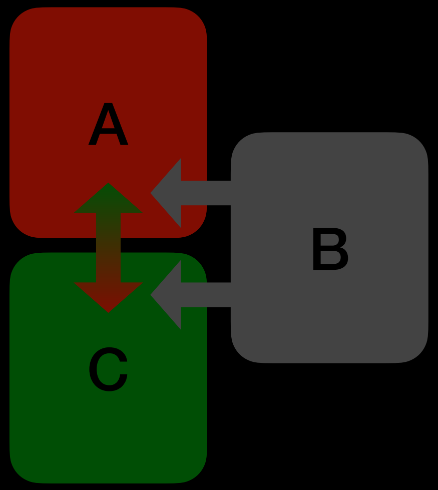
Appendix 16 - Logic - Separation of Concerns (SoC)

Separation of Concerns is achieved by identifying and negating interdependencies between subsystems, ensuring that as much as possible a system is loosely coupled

Tightly coupled systems have interdependencies such that the state of one subsystem is influenced by the state of others

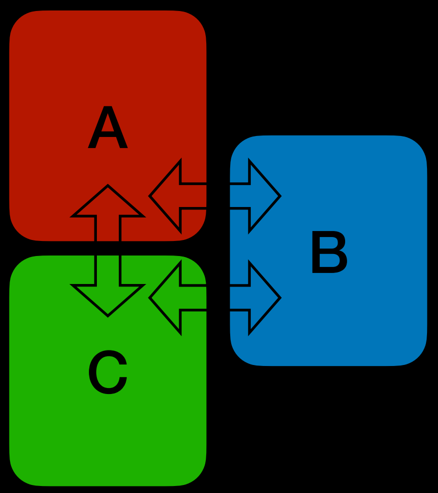


A failure in one subsystem can lead to a cascade of failures that effects the entire system

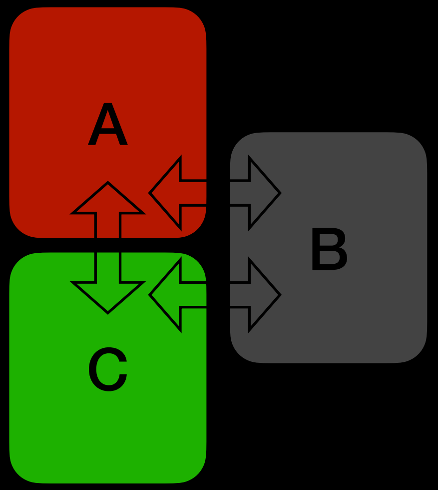


The resilience of a tightly coupled system is a function of the least reliable subsystem

Loosely coupled systems have no interdependencies, meaning the state of one subsystem is not influenced by the state of others



A failure in one subsystem cannot lead to a cascade of failures



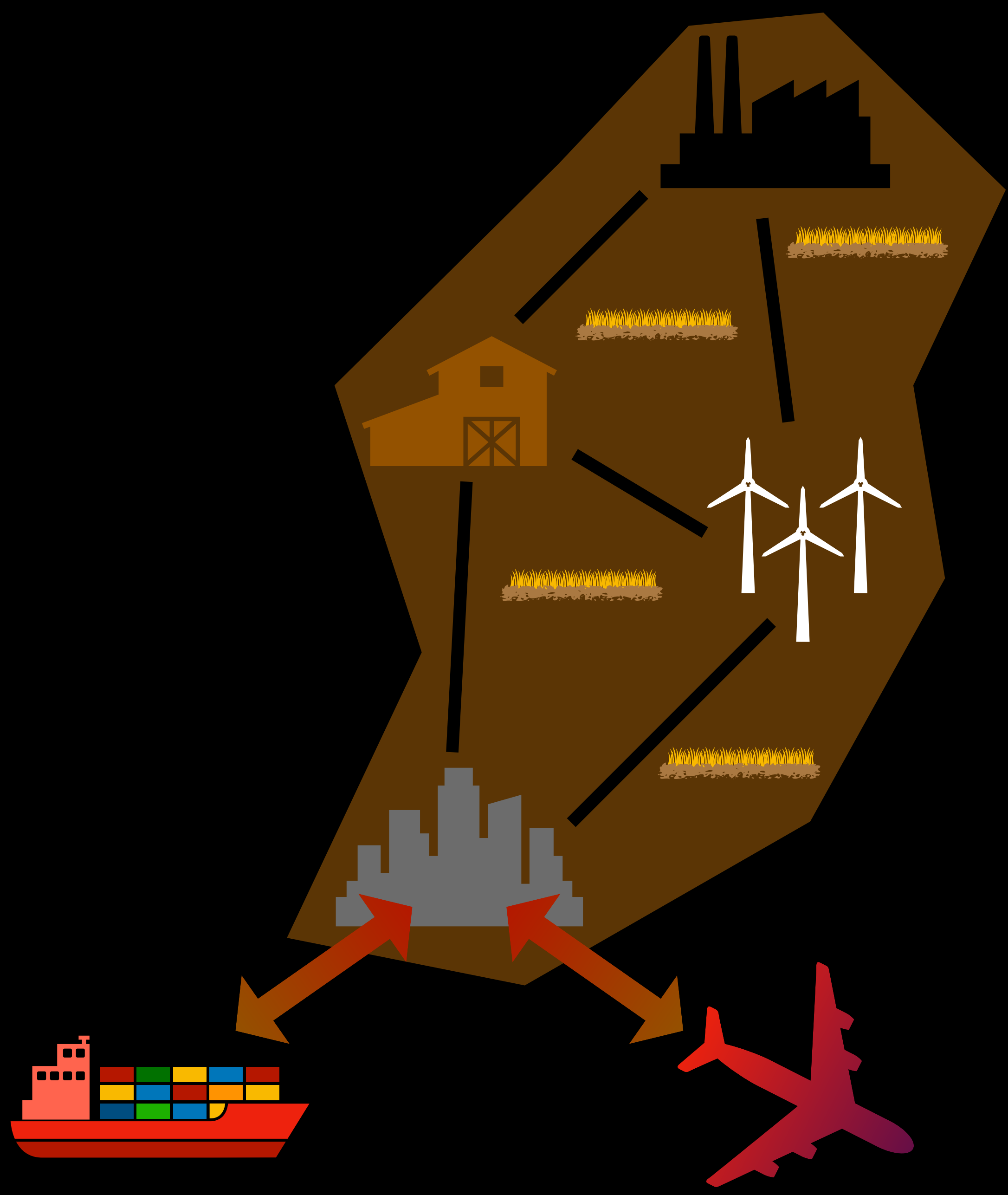
The resilience of a loosely coupled system is a function of the reliability of all subsystems

{Summary} {Open Systems} {Closed Systems} {References}

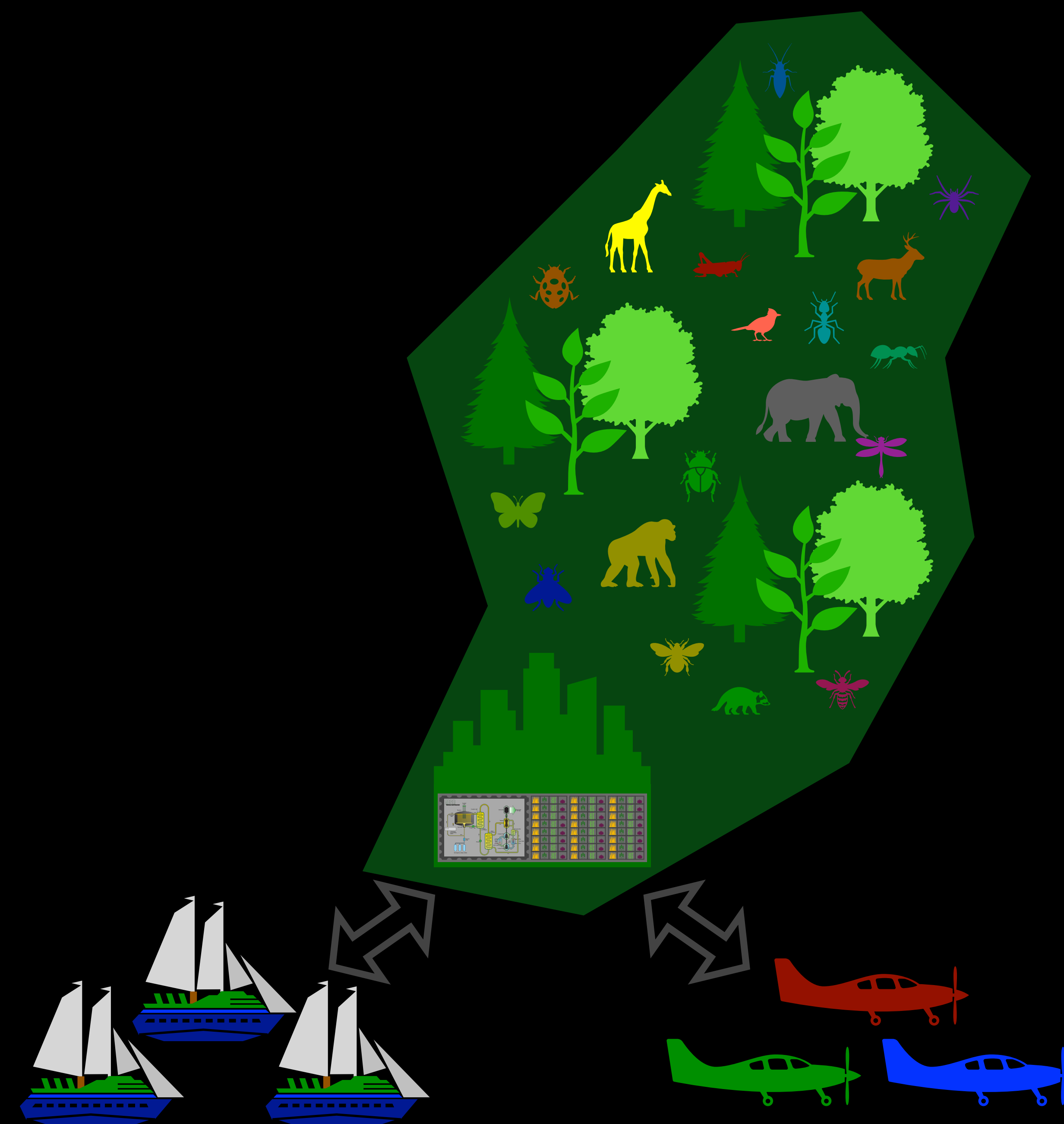
Appendix 17 - Logic - Separation of Concerns (SoC) 2

In practice SoC means consolidating human activity such
that both impact and reliance on the environment is minimal

Sprawling architecture and the need to connect distant components leads the human environment to dominate, leaving most forms of life struggling to survive



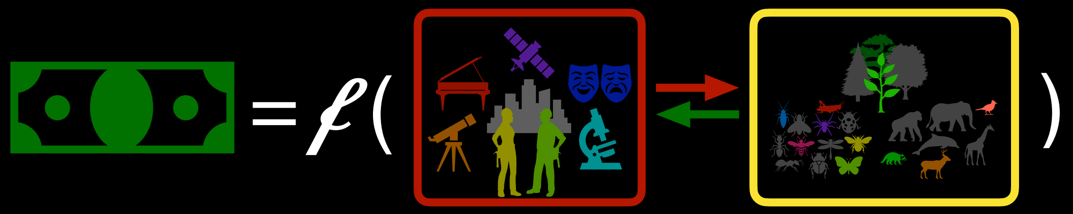
Containing human activity to the smallest possible area allows wild environments to become dominant again. Coupled with vertical agriculture and forrest cities, the Earth will be more productive than at any point in history



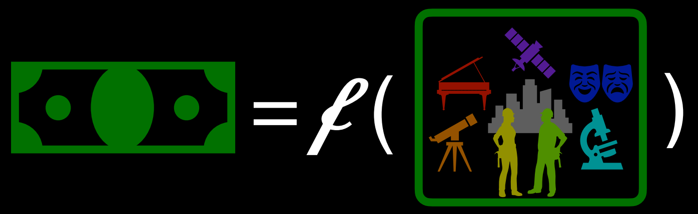
{Summary} {Open Systems} {Closed Systems} {References}

Appendix 18 - Logic - Economics

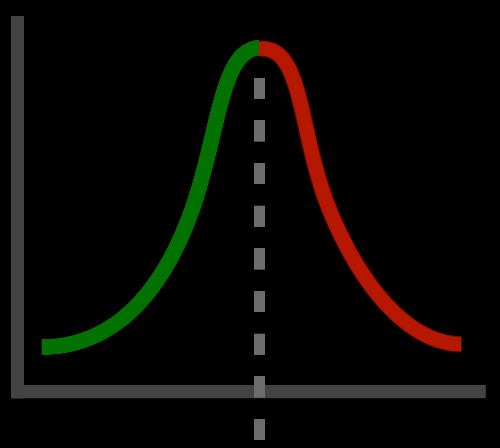
Investment in an economic model that degrades as climate conditions worsen is clearly unwise when all predictions indicate a high probability of them doing so. Investments made in a sustainable economic model are influenced by their market value only, and are resilient to influence from degenerating climate conditions. Therefore a wise investor, i.e one interested in the long-term profitability of a venture, should exclusively favour sustainable over traditional models of value extraction



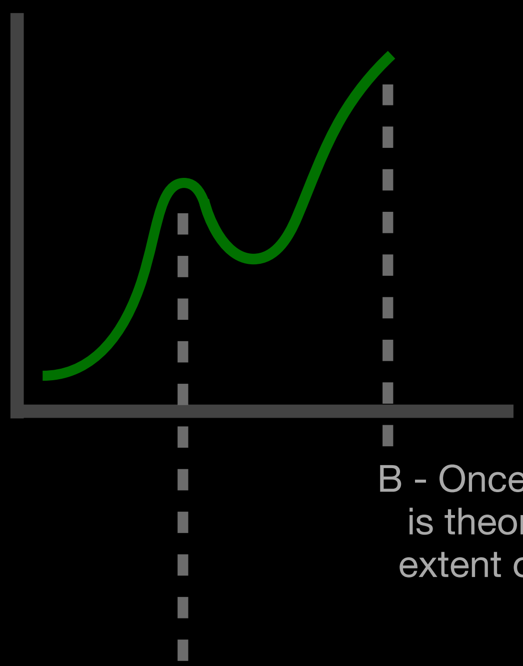
An economic model that extracts value based on a function of two way dependency between human activity and environmental health is unilaterally predicted to run into trouble in the coming century



An economic model that extracts value based on a function of human activity alone is resilient to environmental changes



A - If human activity is tightly coupled to environmental health, and continues to degrade environmental health, then it follows that economic activity will decrease in proportion to the impact of climate change



B - Once SoC is achieved, there is theoretically no limit to the extent of human achievement

A - As human activity is de-coupled from environmental health, there is likely to be a substantial economic cost

This method of value extraction has been applicable for all of human history, but now our impact is such that we must fundamentally reconsider the assumption that value can be extracted from wild environments in perpetuity

This method of value extraction will be applicable regardless of the state of wild environments, ensuring human prosperity and security in the face of climate change

{Summary}

{References}

Appendix 20 - Logic - Optimism

Believing the threat of climate change is not severe, optimistic people are unlikely to be motivated to take significant action

Reaction

Minor system change e.g. community recycling of plastics

Best Case

Worst Case

If the best case projections are true, civilisation will face numerous challenges and degrade somewhat

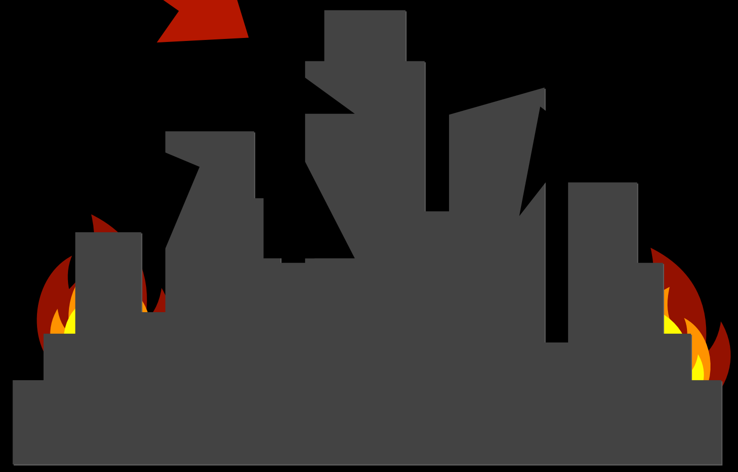
If the worst case projections are true, runaway climate change will result in the end of humanity

Appendix 21 - Logic - Pragmatism

Believing the threat of climate change is severe but requiring proof before taking significant action, pragmatic people are likely to take some action

Moderate system change e.g. carbon neutral by 2050

If the best case projections are true, most of the predicted effects of climate change will have been mitigated, and civilisation will see some benefit from a healthier environment

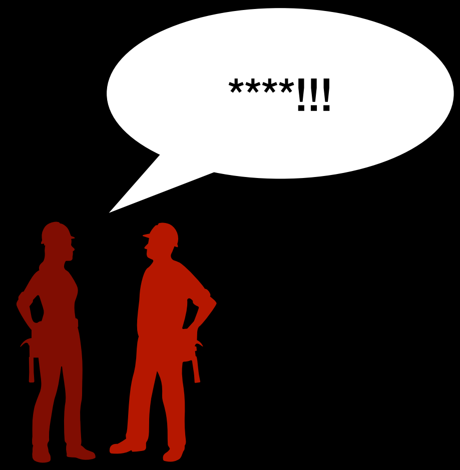


If the worst case projections are true, proof of runaway climate change will come too late to effectively mitigate the effects, resulting in severe degradation of civilisation

{Summary}

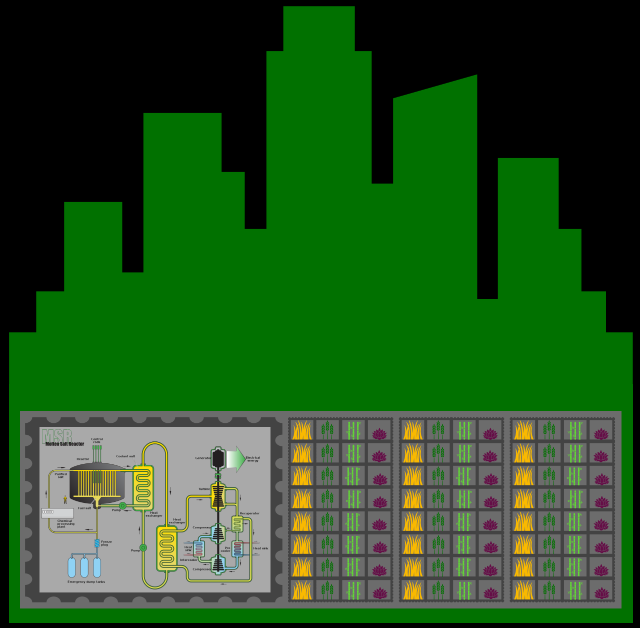
{References}

Appendix 21 - Logic - Pessimism



Believing the threat of climate change is severe and fearing the worst, pessimistic people are likely to take radical action

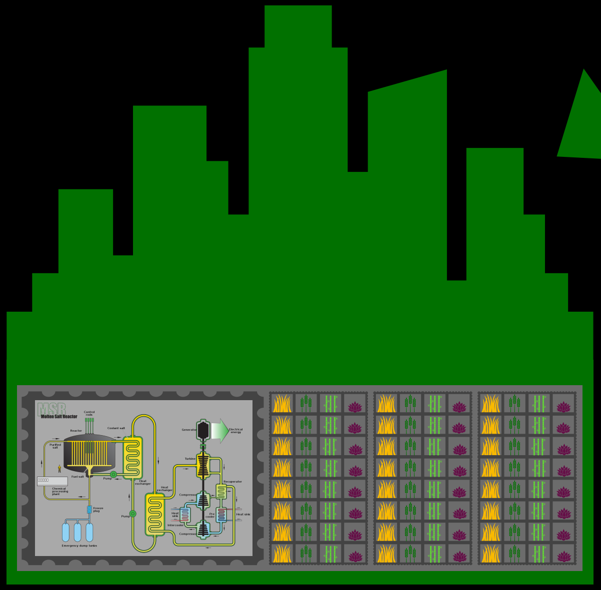
Reaction



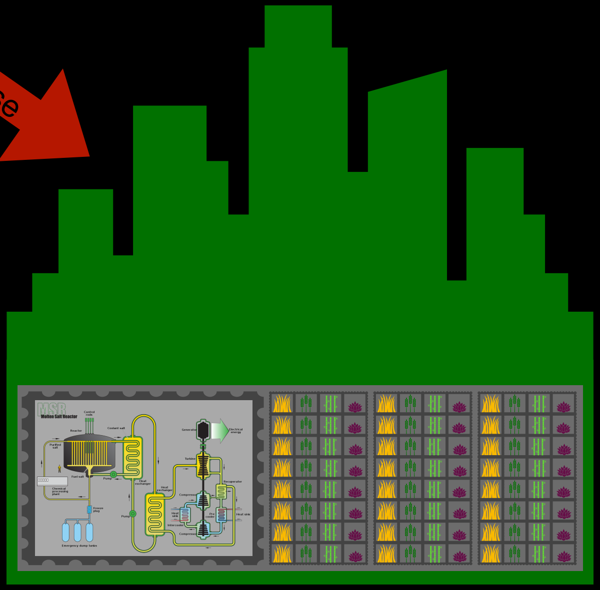
Radical system change e.g. total SoC by 2040

Best Case

Worst Case



If the best case projections are true, all of the predicted effects of climate change will have been mitigated, and human civilisation will reap huge benefits from a healthier environment



If the worst case projections are true, most of the risks presented by climate change will have been mitigated, and human civilisation will be able to continue regardless. If the world tips into a greenhouse state, humans will be in a position to reverse it.

[1] The Guardian - 09/08/21 - Major climate changes inevitable and irreversible – IPCC's starkest warning yet

[2] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [MassonDelmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

[3] IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

[4] Phys.org, 17/09/19: Earth warming more quickly than thought, new climate models show

[5] Scientific American, 19/08/21: Scientists Have Been Underestimating the Pace of Climate Change

[6] Professor Jem Bendell, 27/07/20: Deep Adaptation: A Map for Navigating Climate Tragedy

[7] UK Met Office, Dec 2019: Risk management of climate thresholds and feedbacks: Atlantic Meridional Overturning Circulation (AMOC)

[8] Evaluation of Climate Models, 2013: Flato, G., J. Marotzke, B. Abiodun, P. Braconnot, S.C. Chou, W. Collins, P. Cox, F. Driouech, S. Emori, V. Eyring, C. Forest, P. Gleckler, E. Guilyardi, C. Jakob, V. Kattsov, C. Reason and M. Rummukainen, 2013: Evaluation of Climate Models. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

[9] Trajectories of the Earth System in the Anthropocene, 2018: Will Steffen, Johan Rockström, Katherine Richardson, Timothy M. Lenton, Carl Folke, Diana Liverman, Colin P. Summerhayes, Anthony D. Barnosky, Sarah E. Cornell, Michel Crucifix, Jonathan F. Donges, Ingo Fetzer, Steven J. Lade, Marten Scheffer, Ricarda Winkelmann, Hans Joachim Schellnhuber - Proceedings of the National Academy of Sciences Aug 2018, 115 (33) 8252-8259; DOI: 10.1073/pnas.1810141115

[10] Science Daily, 27/11/19: University of Exeter - Nine climate tipping points now 'active,' warn scientists

[11] Yale Environment 360, 05/12/19: As Climate Change Worsens, A Cascade of Tipping Points Looms

[12] Nature, 27/11/19: Climate tipping points — too risky to bet against

[13] Earth.org, 12/08/2020: A 4.5 Billion-Year History of CO2 in our Atmosphere

[14] Nature, 2017: Foster, G., Royer, D. & Lunt, D. Future climate forcing potentially without precedent in the last 420 million years. *Nat Commun* **8,** 14845

[15] United Nations News, 15/05/18: Climate change: An 'existential threat' to humanity, UN chief warns global summit

[16] Science Daily, 29/10/10: Dramatic climate change is unpredictable

{Summary}

[17] What Is Nuclear by Nick Touran

[18] What Is Nuclear by Nick Touran: Molten Salt Reactors

[19] What Is Nuclear by Nick Touran: Recycling Nuclear Waste and Breeder Reactors

[20] Our World In Data, 10/02/20: What are the safest and cleanest sources of energy?

[21] What is Nuclear by Nick Touran: Nuclear fuel will last us for 4 billion years

[22] BBC Future, 06 /04/17: How vertical farming reinvents agriculture

[23] LettUs Grow's advanced irrigation technology for vertical farms

[24] The Guardian, 17/02/17: Forest cities: the radical plan to save China from air pollution

[25] van de Ven, DJ., Capellan-Peréz, I., Arto, I. *et al.* The potential land requirements and related land use change emissions of solar energy. *Sci Rep* **11,** 2907 (2021)

[26] The Green Alliance: The nutrient cycle - closing the loop

[27] Resources for the Future: Electrification 101

[28] World Nuclear: Hydrogen Production and Uses

[29] Wikipedia: Spaceship Earth

[30] Nature, 07/03/2018: Cleaning up pollutants to protect future health

[31] Science Direct: Human Waste Overview

[32] Centre for Biological Diversity: Halting the Extinction Crisis

[33] Yale 360, 26/01/17: How the World Passed a Carbon Threshold and Why It Matters

[34] Lewis, Simon & Maslin, Mark. (2015). Defining the Anthropocene. Nature. 519. 171-80. 10.1038/nature14258.

[35] Richerson Peter J. and Boyd Robert 2020 The human life history is adapted to exploit the adaptive advantages of culture *Phil. Trans. R. Soc. B***375**2019049820190498

[36] Stockholm Resilience Centre: The nine planetary boundaries

[37] Forsell LM, Åström JA. An Analysis of Resistance to Change Exposed in Individuals' Thoughts and Behaviors. Comprehensive Psychology. January 2012.