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Climate Informed Engineering: An Essential Pillar of Industry 4.0 Transformation

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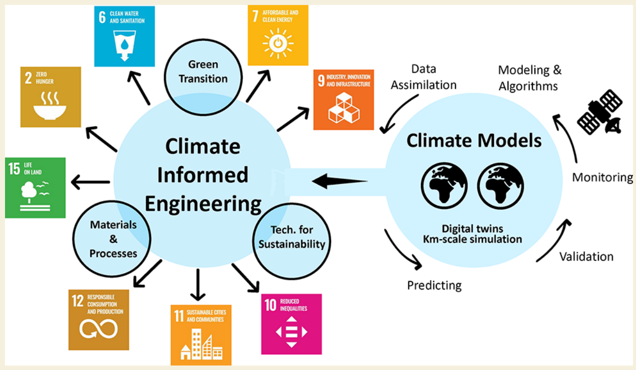
ABSTRACT: Breakthroughs in computing have led to development of new generations of Earth Systems Models providing detailed information on how our planet may locally respond to the ongoing global warming. Access to such climate information systems presents an unprecedented opportunity for engineers to make tangible contributions to climate adaptation through integration of climate information in their products, designs, and services. We introduce the concept of "Climate Informed Engineering" (CIE) as an emerging interdisciplinary field integrating climatic considerations in engineering products and services. The concept behind CIE is to enable engineers to build infrastructure, devices, sensors or develop new materials and processes that are informed by climate and climate change information. We believe CIE will be an increasingly important dimension of Engineering Science resonating with engineers and scientists with different backgrounds.



KEYWORDS: *Climate Informed Engineering, Climate adaptation, Climate change, Technology for sustainable resource management, Green transition*

■ THE CONCEPT BEHIND CLIMATE INFORMED ENGINEERING

It is unequivocal that the Earth's climate is changing.[1] Global temperature and sea level rise, ocean acidification, biodiversity loss, and more frequent and intense droughts, floods, heat waves, and wildfires are simply a few implications of anthropogenic climate change with serious consequences for humans and nature. Over the course of history, humans have been utilizing climate information to plan their activities, grow their communities, and increase their resilience. They used their climate understanding and knowledge to manage agriculture and food production, develop housing, infrastructure, and transportation systems, fabricate clothing and materials for harsh conditions, expand the growth of commerce, and even migrate for survival. A well-known example of the latter is the abandonment of thriving cities in Mesopotamia, the area currently made up of Iraq, northeast Syria, and southeast Turkey, around 4200 years ago as a result of a drying climate and a devastating 300 year long drought.[2] Yet, the common perception of "climate" is, surprisingly, often narrowly limited to the impacts of weather conditions on our day-to-day activities.

Climate, agricultural, socioeconomic, and industrial development are intricately linked,[3] highlighting the relevance of climate information to the design and delivery of a wide range of products and engineering services, especially in a world under a changing climate. While typical climate models provide information at resolutions of around 100 km, recent developments in climate modeling and the unprecedented computational capabilities provided by the fourth industrial revolution have enabled us to aim for developing climate models with the scale resolved at 1 km resolution.[4] The landmark information system of Destination Earth, concerted by the European Union through a billion-euro flagship research program,[5] is one of the major international efforts aiming to construct highly accurate "digital twins" of the Earth[6] on a global scale to monitor and project the interaction between natural phenomena and human activities. Such developments are a step change in the Earth system modeling. The new generation of climate models provides future projections on various climatic parameters incorporating the effects of natural and human perturbations on climate at different scales and delineates how our planet locally responds to the ongoing global warming. This is a

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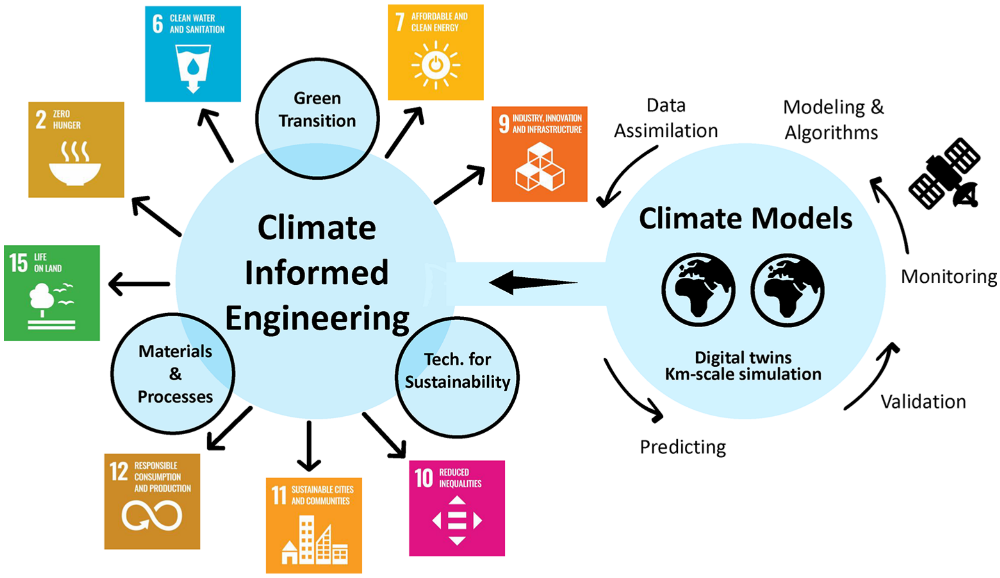

Figure 1. Climate Informed Engineering aims to use and integrate the information obtained by the new generation of climate models in engineering products, solutions, and services, thus contributing to resilience and climate change adaptation which is at the heart of the United Nations Sustainable Development Goals (UN SDGs) especially SDG 2, 6, 7, 9, 10, 11, 12, 15 with their corresponding icons presented in this figure.

Figure 2. Climate Informed Engineering offers solutions to compelling technical challenges brought upon by climate change and projected extreme events. Photo credit: macrovector/Freepik.com.[9]

unique moment in terms of Earth system modeling and climate informatics when models, simulation results, and future projections under different socioeconomics and climate scenarios combined with thematic information are available with fine spatial and temporal resolutions ranging from days to decades.[5,6]

The engineers must seize this unprecedented moment and fully embrace the opportunity to adapt their engineering design, solutions, and products based on the information exploited from the new generation of climate models. The kilometer-scale climate information (present and future) offers an excellent opportunity to transform engineering design and operations toward more sustainable and resilient services under a changing climate. Within this context, the importance of "Climate Informed Engineering" should be highlighted as an emerging interdisciplinary field in the 21st century to integrate climatic elements and considerations in engineering solutions, services, and products. This is precisely at the heart of the United Nations Sustainable Development Goals (UN SDGs)[7] (Figure 1), the Paris Agreement, and The European Green Deal.[8] What the engineers build and the services they offer could be a part of the climate crisis or a part of the solution depending on how informed these products are by the climate information. Climate Informed Engineering will enable

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engineers to build infrastructure, devices, and sensors or develop new materials and processes that are informed by climate and climate change information, thus contributing to concepts like resilience (even to variability within a non-changing climate) as well as climate change adaptation.

■ CLIMATE INFORMED ENGINEER

Climate Informed Engineering necessitates the training of a new generation of engineers informed by climate data who consider climate information in their engineering services similar to the way the economic aspects are considered in their products. Climate Informed Engineering represents an opportunity for transformative changes where both climate scientists and engineers could benefit organically from their core strengths. No matter how much the climate information is accurate and detailed with high spatiotemporal resolution, it will be of little value if not utilized by society in general and specifically by the engineers who are extensively involved in providing functioning solutions for the real-world technical challenges such as developing sustainable materials, machineries and processes for green energy, products, and mobility. A good example of engineering branch that could benefit from Climate Informed Engineering is Civil Engineering. This will enable the civil engineers to design and construct more resilient building, infrastructure and cities in the face of projected climate changes and extreme climate events (Figure 2). A systematic integration of engineering with climate science will contribute significantly to the fight against inequality and climate injustice. A "Climate Informed Engineer" of the future would be able to design and develop more resilient products for difficult times to protect people, businesses, and ecosystems against floods, droughts, heat waves, wildfires, dust storms, hurricanes, and the projected sea level rise (Figure 2).

■ THE ROLE OF UNIVERSITIES

Universities can play a significant role in the campaign for fostering a new generation of Climate Informed Engineers. This could be done by integrating basic climate science and information in engineering education and developing platforms where engineers and climate scientists could exchange ideas and tools. Universities must help to move the next generation of engineering designs and solutions informed by the climate models from the laboratory and academic environment to the market and society. The timing could not be better. Universities should tap into the renewed public interest in climate change, climate-friendly innovations, and rising public awareness over the past decade and take the lead in the integration of climate science into the engineering education. Such efforts will contribute toward developing a shared vision and framework to include climate consideration in engineering services.

Recognizing the importance of climate change and extreme events on engineering products and infrastructure and the responsibility to prepare a new generation of Climate Informed Engineers, a new research initiative focused on Climate Informed Engineering (CIE) has been founded at Hamburg University of Technology (TUHH). CIE resonated with climate scientists and engineers with different backgrounds ranging from chemical, civil, environmental, electrical, and mechanical engineering to energy, soil, material, and computer science and beyond, aiming to train a new class of climate concerned engineers for a world under a changing climate. A wide range of activities are planned in this research initiative including but not limited to developing new courses on the basic climate data and science tailored for the students enrolled in engineering programs, developing collaborative proposals for funding, and coordination of annual meetings serving as a platform for exchanges between politicians, experts from industry, academics, students, and the general public. To further integrate climate information in engineering, this initiative is involved in the development of a field-scale Mini Living Lab which will be used in the teaching and research activities relevant to Climate Informed Engineering. The Mini Living Lab offers an excellent opportunity to combine sensing technology, big data acquisition and analysis, and climate information with a variety of environmental and engineering topics related to soil, water, climate, wind, energy, and sustainable resource management. Moreover, this initiative places a particular focus on Citizen Science activities related to Climate Informed Engineering. The goal is to empower the next generation of Citizen Scientists in which science and society will have active interactions on sensing technologies and engineering topics informed by the climate information. Within this research initiative, the new role of "Citizen Science Ambassador" has been created to sustain and promote communications and coordination of efforts between the university and society with a particular focus on high school students. Such efforts will enable us to mobilize our resources effectively toward establishing impact-driven research environment that makes it easier for citizens to understand the value of investments in Climate Informed Engineering and innovations. The foundation of such a research initiative at TUHH can serve as a model for future development of what we believe will be an increasingly important dimension of Engineering Science.

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Notes

The authors declare no competing financial interest.

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Figure 2, the "Natural disasters set", was created by macrovector/Freepik.com and distributed with free license which is greatly acknowledged.

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