Engineering Research Challenges (ERC)

All research funding agencies (e.g. [ARC](http://www.science.gov.au/scienceGov/ScienceAndResearchPriorities/Pages/default.aspx) and [ACARP](http://www.acarp.com.au/Media/ACARPResearchPrioritiesNewsletter.pdf)) put constraints on the types of projects that they will fund. In the coursework research context of the UNSW Masters programs, each academic will have their own research interests and so choice of project topic comes down, at least in part, to a [choice of supervisor](https://research.unsw.edu.au/researcher). In this course, we simulate this real-world context by limiting projects to twenty Engineering Research Challenges, categorised under four broad headings.

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| Energy |

## 01. Energy Storage

Our evolving energy systems with increased intermittent energy generation need energy storage possibilities if we are to use energy most efficiently. Technology options include, for example, batteries, fuel cells, pumped storage, or heat storage.

## 02. Transforming the electricity grid for 100% renewable energy

The technological capability already exists to meet all our electricity needs with renewable energy generation. The big challenge that remains is to enable the integration of new technologies, distributed energy, smart metering, energy storage, intermittent energy sources, and so forth, into our electricity grid.

## 03. Further reducing the cost of renewable electricity

This means increasing the performance as well as lowering the manufacturing and installation costs for systems. This applies to all renewable energy technologies including photovoltaics, solar thermal, wind, biomass, tidal, and so forth.

## 04. Alternative fuels development

To wean society off its dependence on oil and gas, we need alternative fuel options for transport and industry, such as biofuels.

## 05. Maximising hydrocarbon reserves

Hydrocarbon reserves are oil and gas deposits that can be commercially recovered. The two main ways to maximise the reserves are to increase the recovery factor from conventional reservoirs using Enhanced Oil Recovery (EOR) techniques and to exploit unconventional resources (including shale gas, shale oil, tight gas, coal seam gas, heavy oil, and methane hydrates)

## 06. Carbon capture and storage

To reduce greenhouse gas emissions and limit the impacts of burning fossil fuels during the transition to cleaner energy technologies.

## 07. Sustainable resource recovery

Examples include reducing the impact and energy use of mining techniques, exploration and data collection; developing more efficient mineral refining; and land rehabilitation technologies.

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| Computing |

## 08. Network & data security

Modern life is becoming more and more dependent on services that run on the Internet. Many of these services are critical (*e.g.* health care monitoring) and personal (*e.g.* banking). It is imperative that the network provides a highly secure and efficient backbone.

## 09. Handling Big Data

Research in science and engineering is being transformed by our ability to manipulate vast quantities of data. To further advance the effective use of such data, we need efficient technologies for storing and retrieving it, and new large-scale computational approaches for analysing it.

## 10. Internet of Things

The current manifestation of the Internet is primarily a vast collection of networked computers and, increasingly, hand-held devices (such as smart phones). In the future, computers (as we understand them, *i.e.* servers, laptops, tablets) will be hugely outnumbered by simple embedded computational devices (*e.g.* in goods and home appliances). We need to develop new computational models to make effective use of the large amounts of data that these devices will provide.

## 11. Quantum limitations of electronics

Currently, there are two approaches being pursued in parallel: (1) in the 'continuum' domain, researchers are pushing microelectronics devices smaller and smaller, making incremental progress and; (2) in the 'quantum computing' domain, researchers are using a fundamentally different approach to electronics. At some point, the two approaches will need to be merged.

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| Infrastructure |

## 12. Sustainable buildings (and infrastructure)

It seems we live in an increasingly disposable society We need to consider engineering building materials and building designs, with a focus on recyclability, designing buildings for durability, not for a 20-year (or less!) lifespan!

## 13. Transport infrastructure

Efficient transport systems to service expanding cities, low emissions transport technologies, well-integrated transport systems in urban landscapes to promote sustainable communities.

## 14. Global access to clean water

Water collection and filtering technologies for developing countries, water distribution infrastructure development.

## 15. Sustainable water systems

Options include low energy water systems, sensors and monitoring for water quality, water efficiency technologies, national water management, and desalination, among others.

## 16. Sustainable food production

Managing the nitrogen and phosphorus cycles, efficient fertiliser application and minimising runoff and erosion, reducing emissions from soils and water systems, recycling organic waste and manure, and capturing useful gases.

## 17. Sustainable waste management

Waste recovery, such as phosphorus recovery from sewage, recovering recyclable materials. Industrial ecology, closed loop systems, and so forth.

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| Other |

## 18. New medical treatments

Engineers also have a role to play in medical research. For example, chemical and nanoparticle design for new cancer treatments. Nanomedicine is a large and emergent field. Nanoparticles, such as liposome, polymer nanoparticles, gold nanoparticles, etc. have been approved for drug delivery and photothermal therapy for safer and more efficacious therapeutic outcomes.

## 19. Advanced materials

Often, the building blocks for new technologies are new materials. Labs around the world are discovering and developing new materials with useful properties, but it is a slow process from discovery to application and widespread use, usually decades. Some examples of current exciting focus areas are biomimicry materials, 3D printed materials, carbon materials (carbon nanotubes, graphene, etc), porous materials and smart materials that have superior properties that can be changed by external stimuli.

## 20. What is the role of engineering into the future?

A somewhat philosophical and thus challenging challenge (!) for Engineers. Engineers do technology. Their mission seems to be to improve humanity's material standard of living — to "solve the problems" of societies by devising new and ever more ingenious ways to provide the necessities and luxuries of modern human life. However, this process has not always had a benign impact on the environment, societies and individuals. What then, should be the mission of engineering, and what things should we be doing differently?