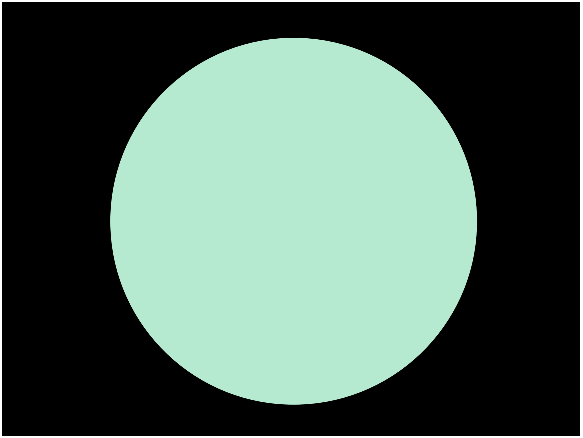
engineering where ecology meets economy

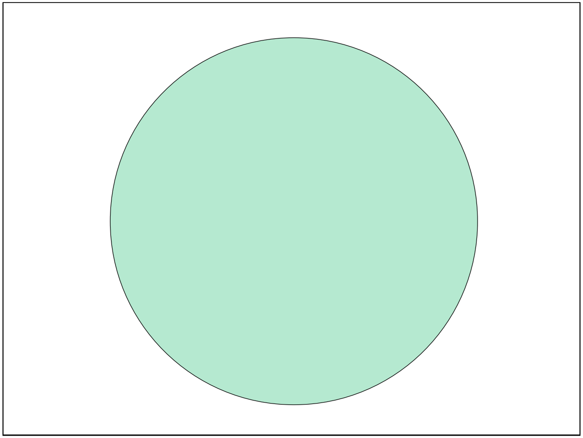
David Painter
September 2006

This was originally an in-house presentation to departmental colleagues at the University of Canterbury. It was later presented again to a wider group in the College of Engineering at the University. This .pdf file has been edited slightly.

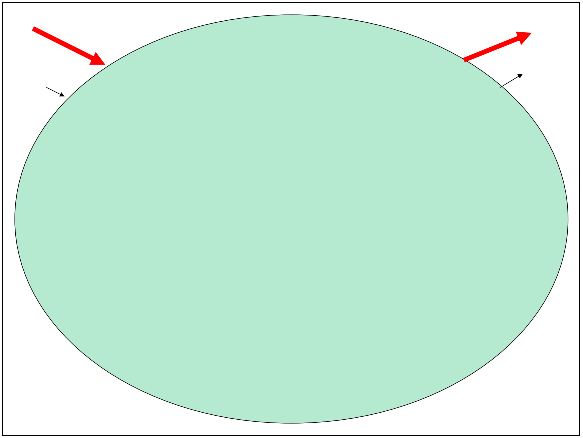
That we presently have just one planet available to live on is now well-recognised.



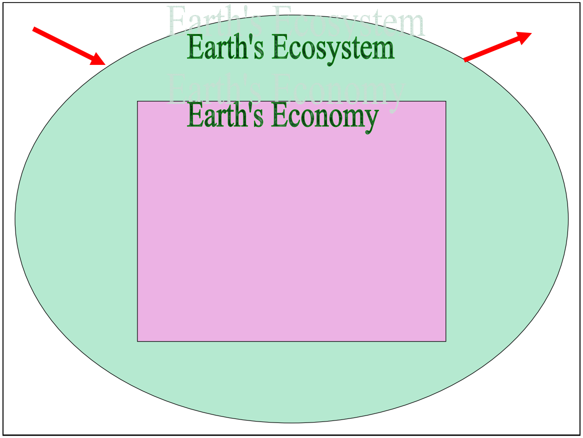
Let us simplify it, …



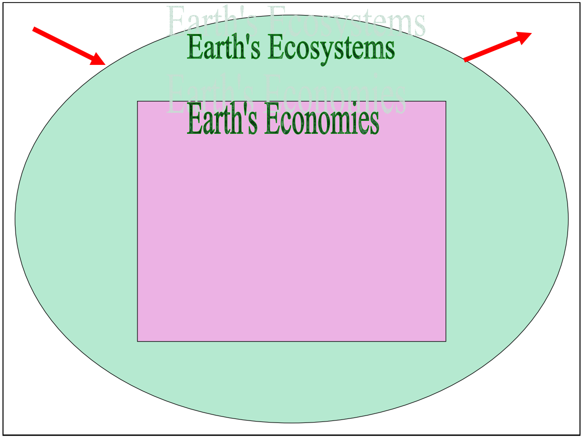
… take away all the dark matter and dark energy, …



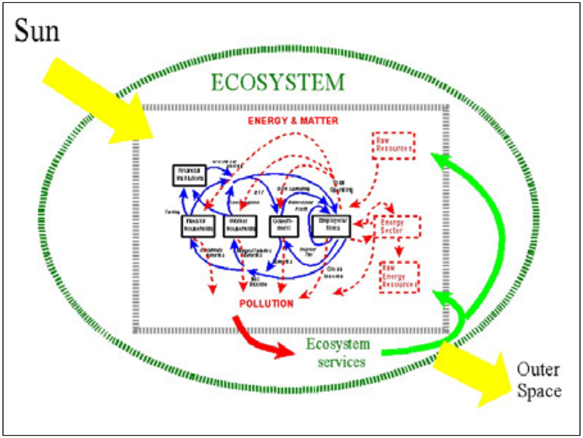
… then make it a bit more of an ellipsoid, as it is. Now we can diagrammatically examine mass [red] and energy [black] flows and balances. Earth both receives and emits radiation. Energy received is almost entirely that provided by our sun. There isn't much mass exchange with space: a bit of hydrogen escaping the atmosphere and the occasional meteorite arriving, or a satellite or rocket departing or returning.



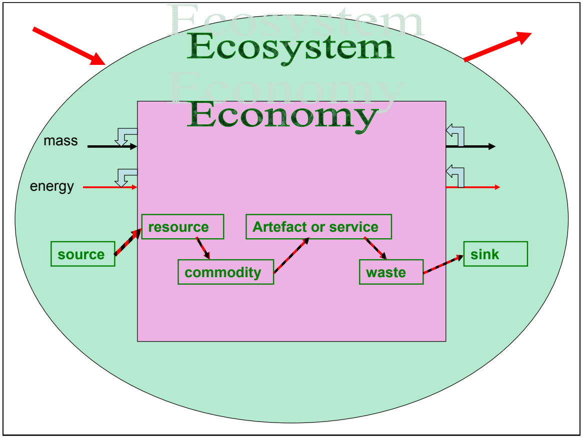
So we can neglect mass exchange across the system boundary drawn a suitable distance above Earth’s surface. The entire Earth’s ecosystem is contained inside the boundary. Inside and nearly throughout Earth’s ecosystem is the human economy. It is fair to note that there are ecosystems within Earth’s human economy, but as a simplified representation, this will do for now.



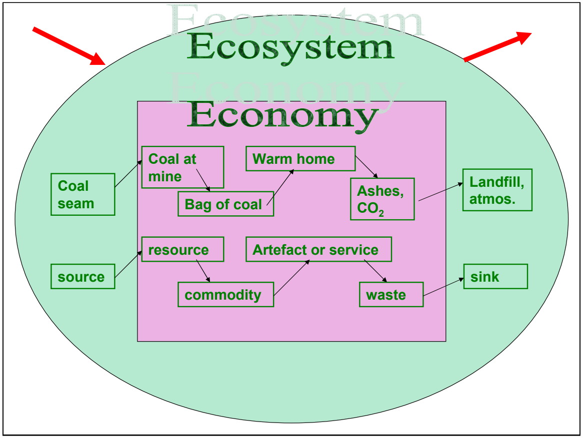
It is also fair to note that there are many different kinds of ecosystems, in many different places. Likewise, there are many different human economies and they too occur in many different places.



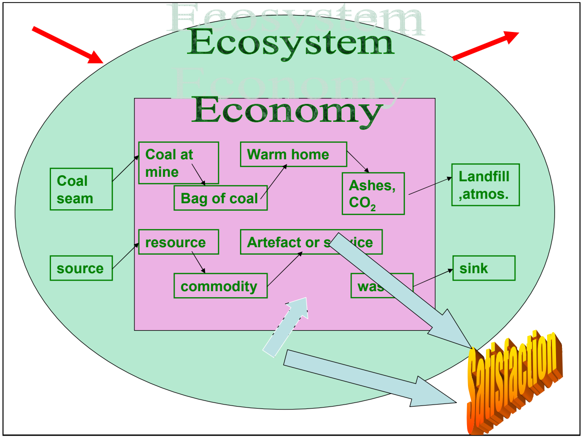
Here is an alternative representation of Earth's ecosystem, also considering energy and mass flows. This one is due to Dr John Peet [Reference: Peet, NJ Sustainability in New Zealand: Lifting the Game. Background paper to the]Sustainability Forum of the Parliamentary Commissioner for the Environment, 2007]



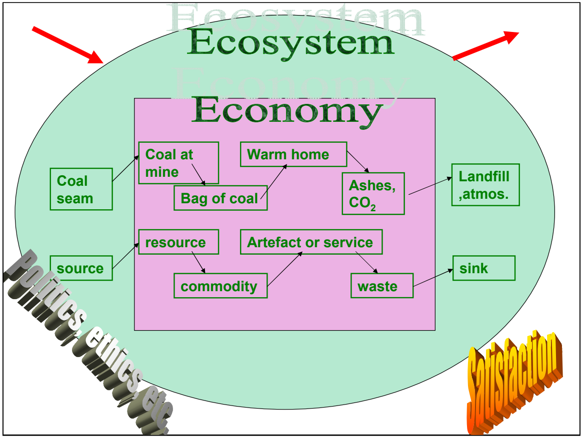
My present purpose is to provide a partial taxonomy of professional engineering. We stay with my simplified representation of Earth's ecosystem and the human economy within it and consider the mass and energy flows from the ecosystem into the economy, then from the economy back into the ecosystem. These flows can be considered as coming from a **source** in the ecosystem. When that source is recognised as having economic value it becomes a **resource**. A resource can be turned into a **commodity** to provide an **artefact** or **service**. Inevitably, there will be a **waste** and this must be returned to a **sink** in the ecosystem.



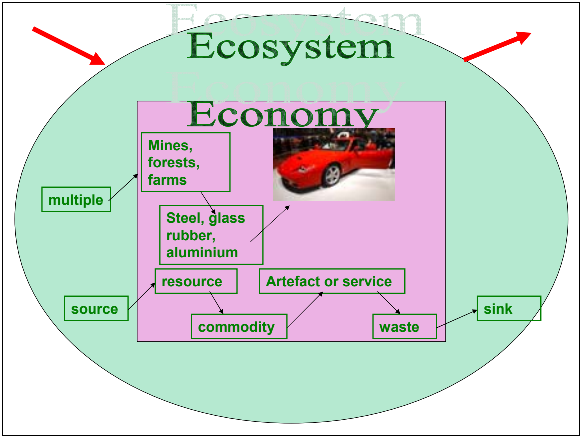
Consider a seam of coal underground or near the land surface. At a very small scale, someone might recognise the coal's value and obtain a mining licence. The **source** has become a **resource**. Once it is mined and bagged it has become a **commodity** which can be sold and bought. The **service** it provides is a warm home. But that is not the end of the story. The solid **waste** is ash, which will end up in the household garden or in a landfill as the **sink**. The gaseous **waste**, mainly CO_2, ends up in the atmosphere as the **sink**. Clearly this example can be scaled up to industrial mining.



Note that in our simplified consideration of mass and energy flows we are leaving out some very important aspects of human life. The warm home service is not an end in itself. It provides freedom from the health dangers of extreme cold and provides an enjoyable interior environment – in one word, satisfaction. Not all examples of satisfaction arise from artefacts and services in the human economy. Some arise directly from the ecosystem; and some attributes of the economy benefit from ecosystem services other than specific sources.

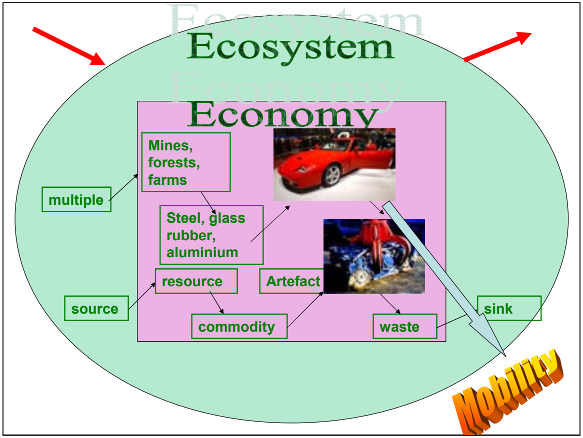


Note also that there are a whole lot of other aspects of human life not dealt with here: politics, ethics, culture – we are pursuing a description of engineering activities by considering mass and energy flows. This will prove to be sufficient, although there is no suggestion that the other aspects are irrelevant or unimportant!



Often multiple sources and resources are involved in producing one artefact or service.

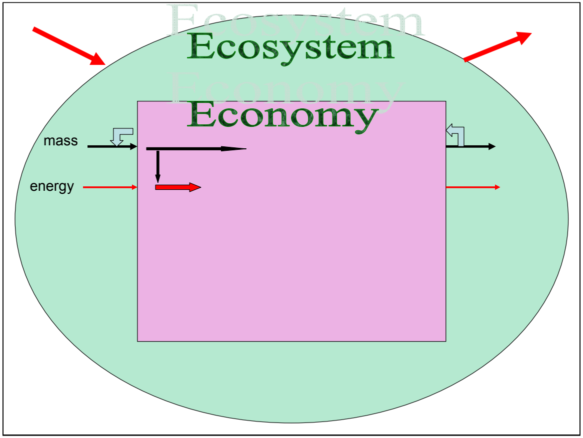
It might be an artefact considered to be very desirable and providing great satisfaction. And …



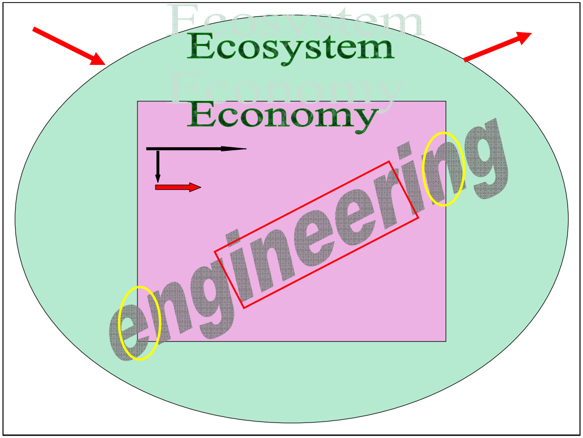
… it might provide the satisfaction of mobility, and more subtle pleasures. But, two owners and one coat of paint later it still becomes waste.

And that waste still has to find a sink in the ecosystem.

Sometimes that sink is a severe disservice to the ecosystem!



Now this is where this story **really** begins! Because there is one human activity which is primarily concerned with transforming sources and resources into artefacts and services by modifying mass and energy flows.



That activity is engineering. Most engineering occurs within the human economy [‘in eer’]; some also occurs at the boundary between economy and ecosystem.

engineering is
creative art
based on science
for useful purposes

This is not one of the ‘traditional’ definitions. It is one Dr Tim Davies and I put forward in 1990 [Reference: Davies, T.R.H.; Painter, D.J. New Degree in Natural Resources Engineering, N.Z. Engineering, 1 July 1990]

engineering is
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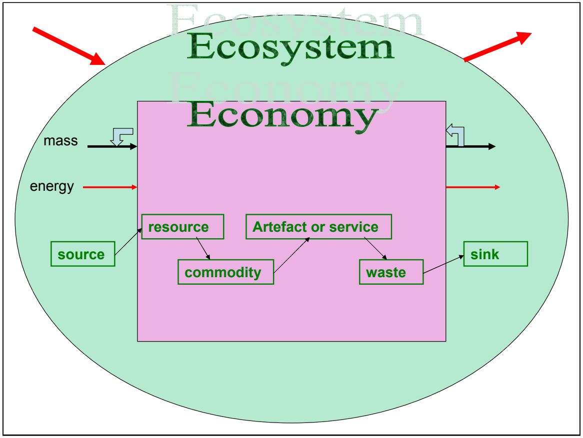
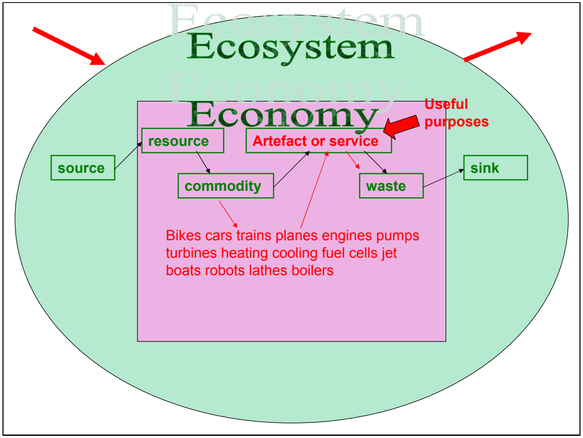
for useful purposes

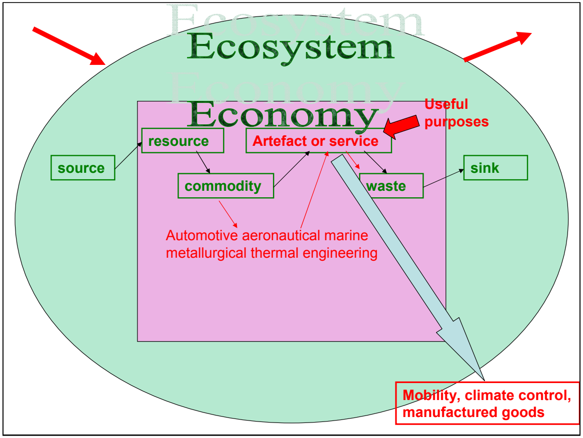
The useful purposes, in the present context, have mainly been thought of as the artefacts and services of our system diagram. But as we shall see, the useful purposes are also very much concerned with the sources, resources, commodities, wastes and sinks.



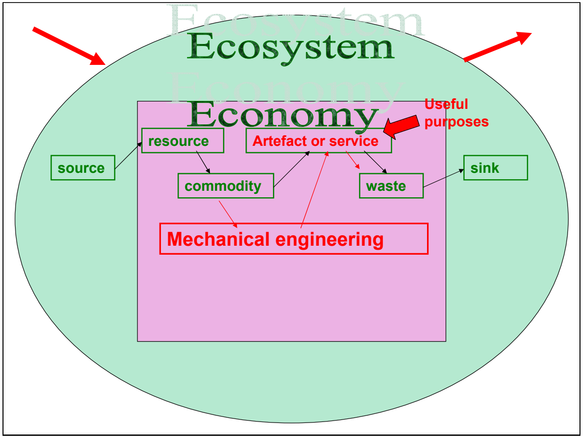
We return to our system diagram and include on it a group of recognisable common artefacts and services.



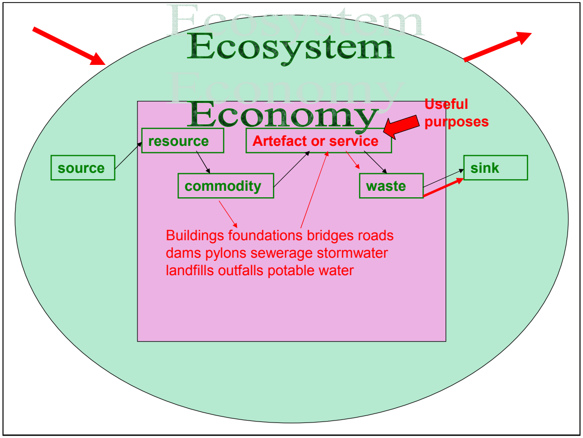
The engineering most clearly associated with providing this group of artefacts and services …



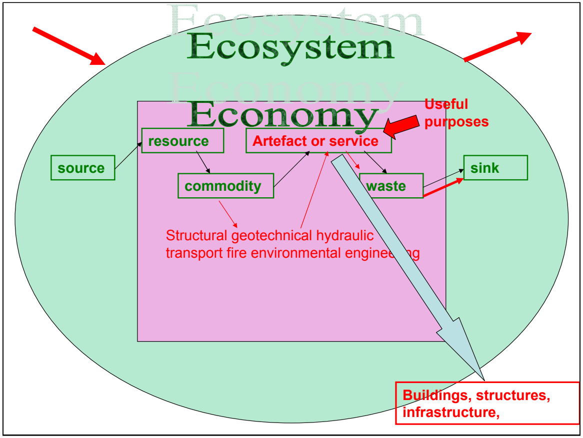
… can be associated with these names of particular **specialisations** of professional engineering. The artefacts and services are primarily concerned with the satisfactions of mobility, climate control and manufactured goods made from relatively inert materials. Those **specialisations** can all be considered to be …



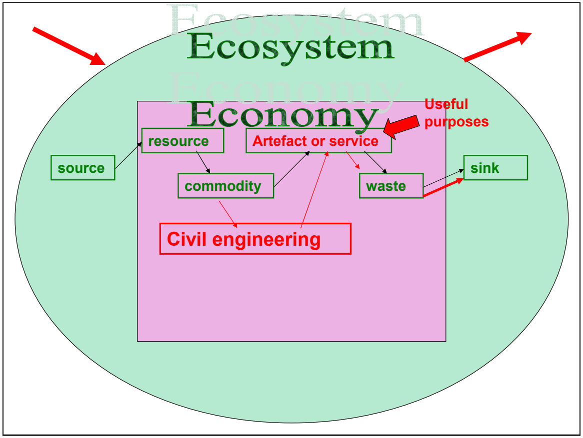
… part of the **sub-discipline** of **Mechanical Engineering**.



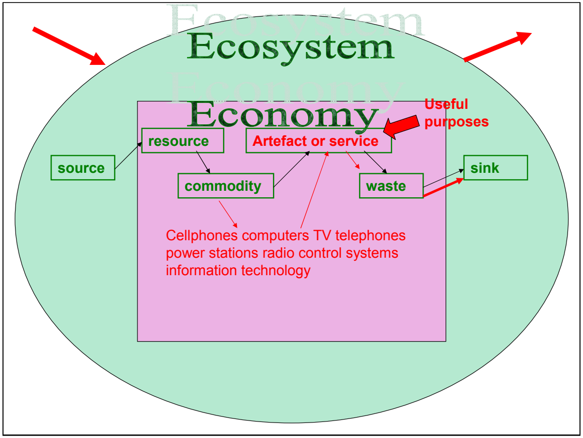
The engineering most clearly associated with providing this group of artefacts and services …



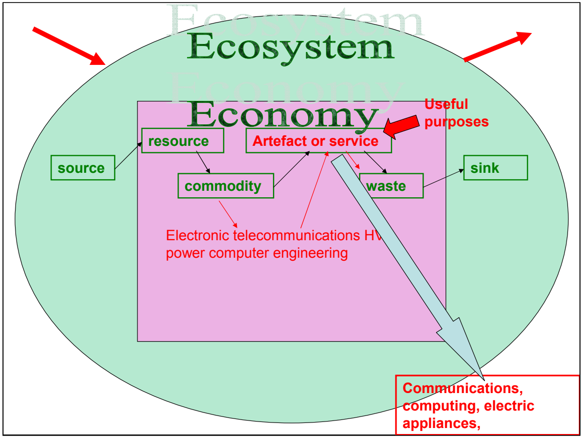
… can be associated with these names of particular **specialisations** of professional engineering. The artefacts and services are primarily concerned with the satisfactions provided by buildings, structures and infrastructure made from relatively inert materials. Those **specialisations** can all be considered to be …



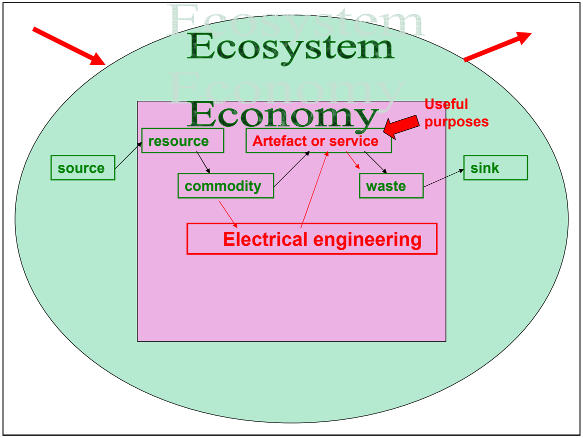
… part of the **sub-discipline** of **Civil Engineering**.



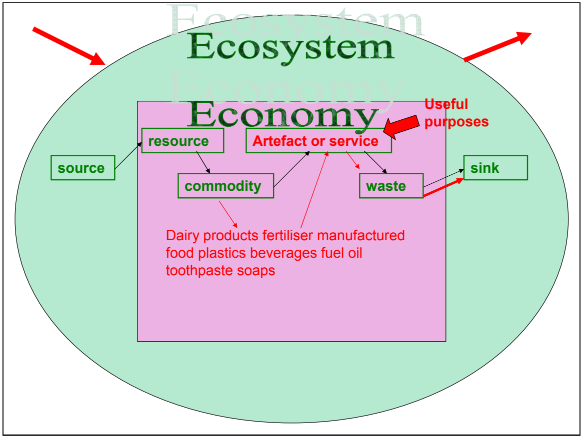
The engineering most clearly associated with providing this group of artefacts and services …



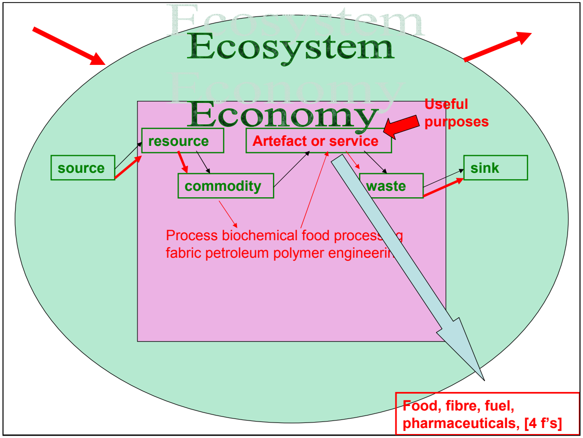
… can be associated with these names of particular **specialisations** of professional engineering. The artefacts and services are primarily concerned with the satisfactions of communications, computing and electronic appliances made from relatively inert materials. Those **specialisations** can all be considered to be …



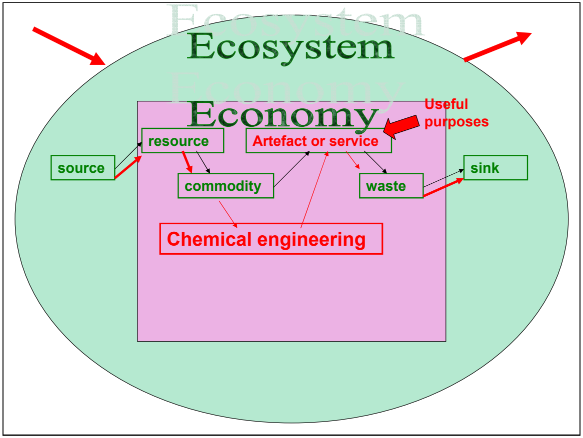
… part of the **sub-discipline** of **Electrical Engineering**.



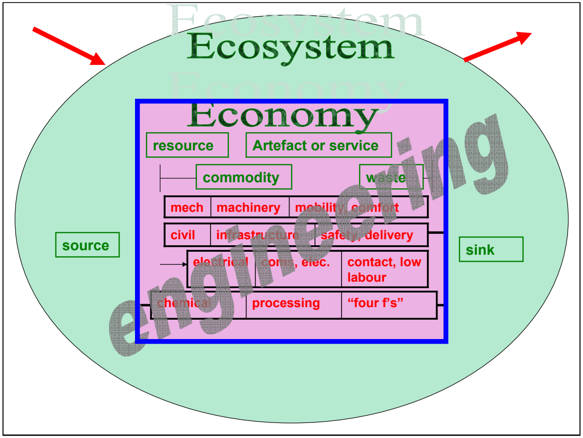
The engineering most clearly associated with providing this group of artefacts and services …



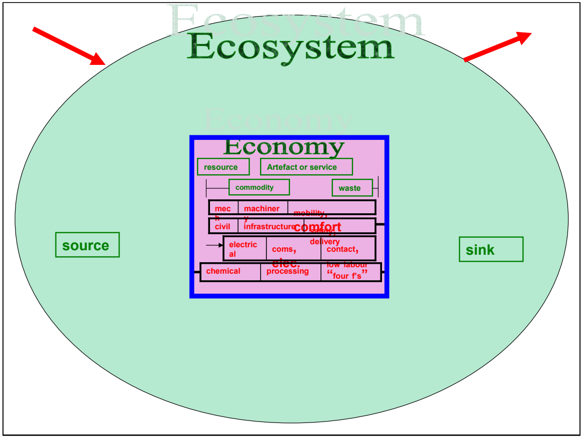
… can be associated with these names of particular **specialisations** of professional engineering. The artefacts and services are primarily concerned with the satisfactions of food, fibre, fuels and pharmaceuticals. No longer are we considering mainly inert materials. Those **specialisations** can all be considered to be …



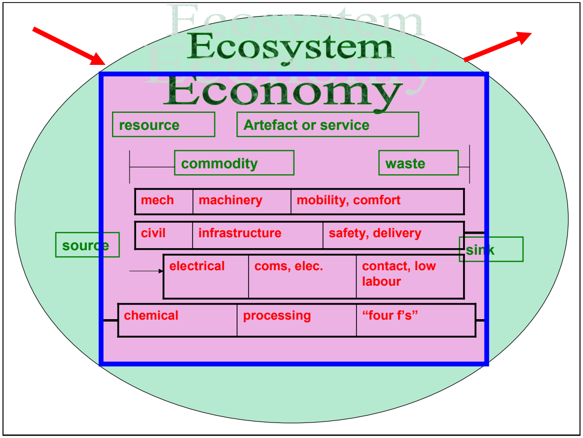
… part of the **sub-discipline** of **Chemical Engineering**.



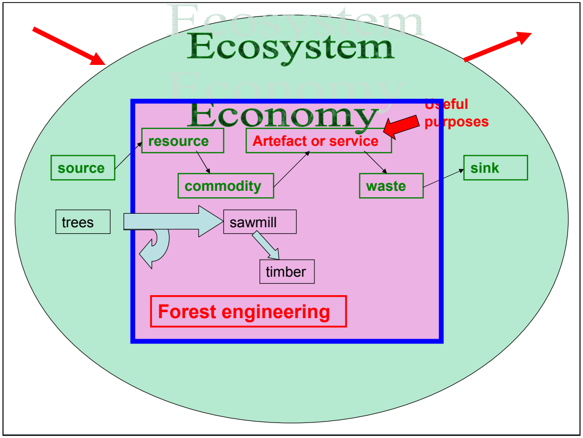
If we consider professional engineering to be a **discipline**, then those four are the **sub-disciplines** of engineering most concerned with engineering within the human economy.



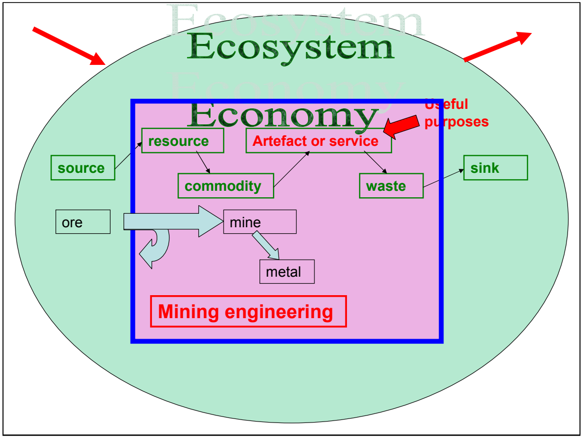
There was a time when the human economy was relatively small compared to Earth's ecosystem; there were many sources and sinks unexploited.



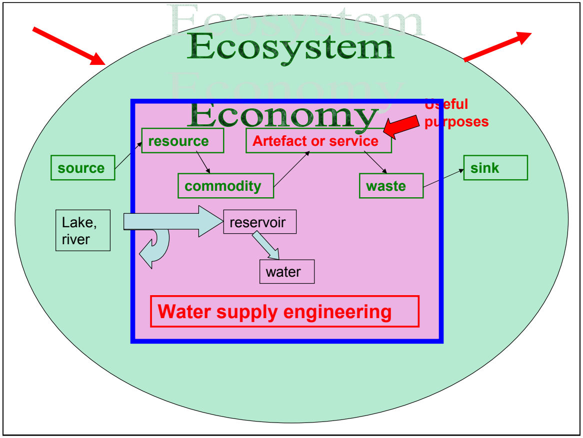
But the human economy has grown, while the Earth's ecosystem is finite and relatively unchanged in 'size', total mass and total energy available. So the kinds of engineering which are not primarily within the human economy, but at the boundary where the economy meets the ecosystem, now assume great importance.



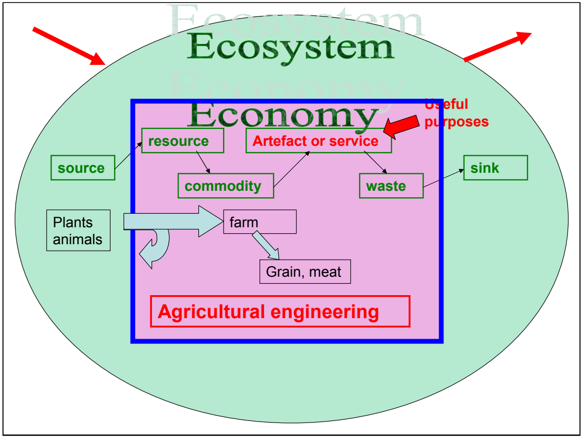
Forest Engineering is concerned both with creating plantation forests [economy to ecosystem] and with harvesting trees [ecosystem to economy]. It is also concerned with sustainable forests, which can involve services **to** the ecosystem ['negative' ecosystem services]. Forest Engineering occurs mostly at the boundary between human economy and ecosystem.



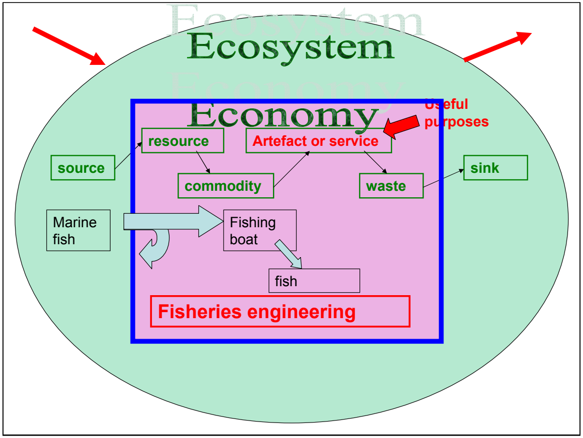
Mining Engineering is very similar to Forest Engineering, but its ‘trees’ are either long since transformed [to coal], or never were alive [gold, uranium, rare earth and other metals].



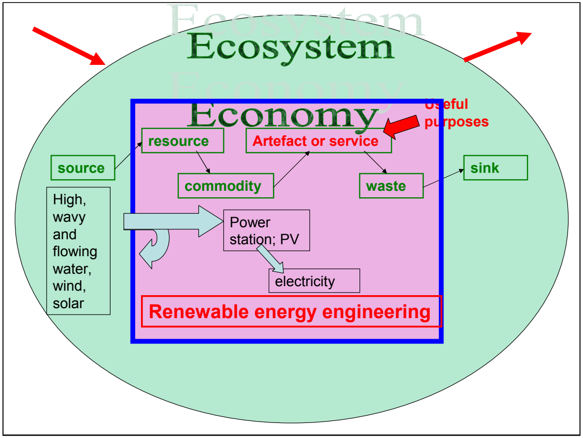
The nature of the ‘mass’ changes, from trees, to ore, to water, but all these involve engineering at the economy/ecosystem boundary.



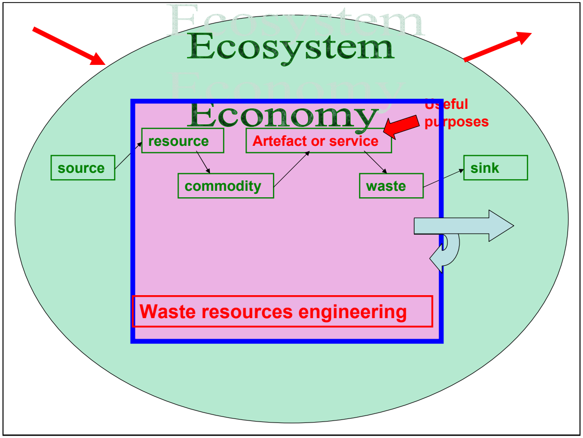
Agricultural Engineering is a very ancient form of engineering at the boundary; arguably blacksmiths and irrigation engineers preceded pyramid builders!



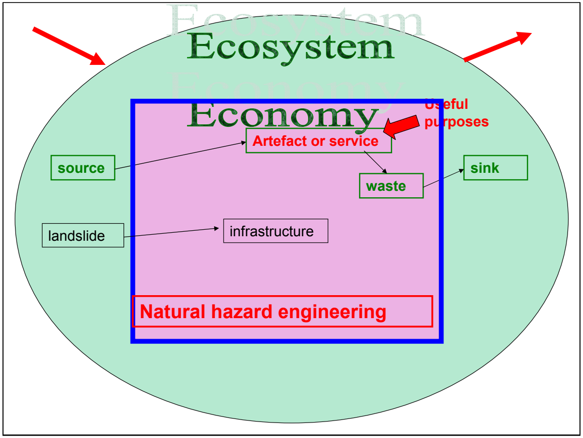
And **Fisheries Engineering** is much like Agricultural Engineering gone to sea.



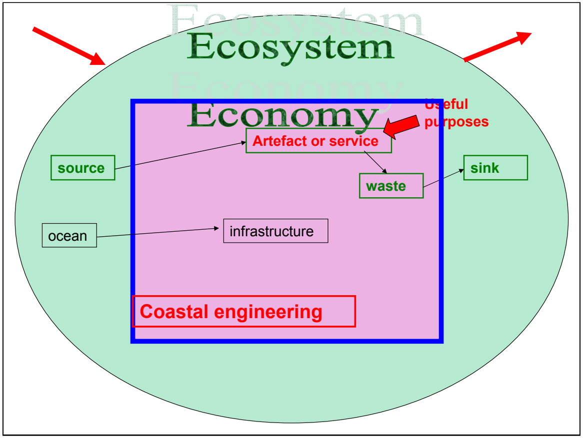
The manufactured technology and infrastructure for Renewable Energy Engineering might well be in the domains of Mechanical, Civil and Electrical Engineering. The engineering specific to the source-resource transformations, including effects on ecosystems, clearly resembles other engineering at the economy/ecosystem boundary.



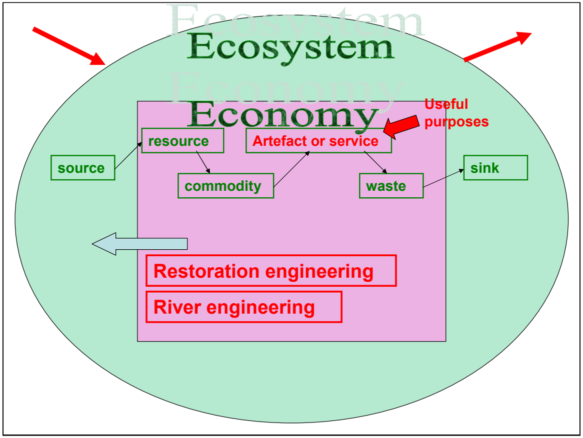
Waste Engineering is best referred to as **Waste Resources Engineering**, as many wastes can also become resources for a further process. Waste Resources Engineering differs from the preceding forms of engineering at the economy/ecosystem boundary by being concerned with waste-to-sink transformations, rather than source-to-resource transformations.



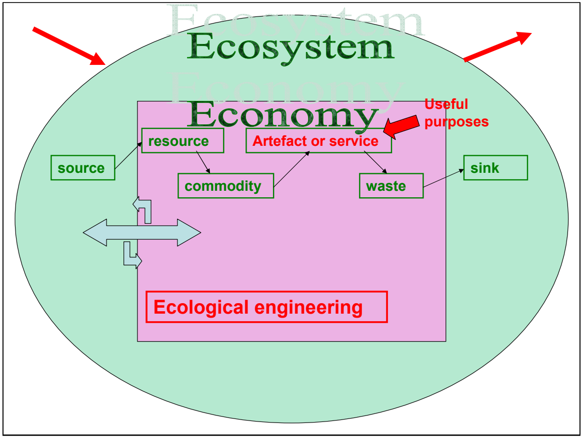
This form of engineering differs somewhat from other trans-boundary engineering because there are no ‘resources’ directly involved.



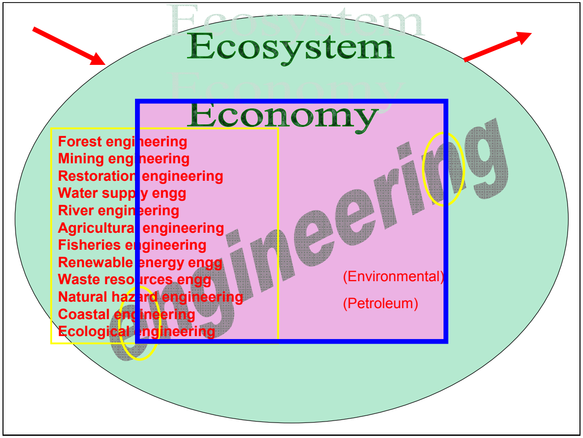
Coastal Engineering is sometimes a marine form of Natural Hazard Engineering, but can also be concerned, like Civil Engineering, with marine and coastal structures and infrastructure.



As mentioned earlier, in relation to Forest Engineering, there are forms of engineering specifically concerned, not with ecosystem services [from ecosystem to economy], but with 'negative' ecosystem services [from economy to ecosystem]. River Engineering is a particular form of Restoration Engineering. 'Restoration' is often not possible and there are many other 'R-words' to choose from: reclamation; rehabilitation; remediation; recovery. But Restoration Engineering seems to be favoured.



Ecological Engineering is relatively recent [since the 1960s] and arose out of applied ecology, rather than out of engineering. It can be thought of as designing, creating and restoring ecosystems, thus putting it firmly astride the economy/ecosystem boundary. Initially it has been much concerned with wetlands, aquaculture and ecosystem rehabilitation.



So we have now gathered a dozen forms of 'engineering at the boundary'. We should also note that two specialisations previously mentioned as parts of Civil and Chemical Engineering, respectively, are also often involved at this boundary – Environmental Engineering and Petroleum Engineering.

Engineering at the border

Forest engineering
Mining engineering
Restoration engineering
Water supply engg
River engineering
Agricultural engineering
Fisheries engineering
Renewable energy engg
Waste resources engg
Natural hazard engineering
Coastal engineering
Ecological engineering

Of these dozen forms of engineering, …

Restoration engineering
Water supply engg
River engineering

Renewable energy engg
Waste resources engg
Natural hazard engineering

Forest engineering
Mining engineering

Agricultural engineering

Fisheries engineering

Coastal engineering

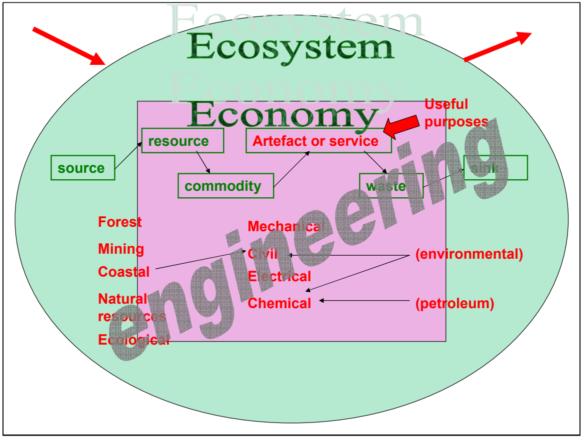
Ecological engineering

… six are now well-established. Agricultural Engineering has undergone various name changes internationally, to Biosystems, Bioresources or Biological Engineering.

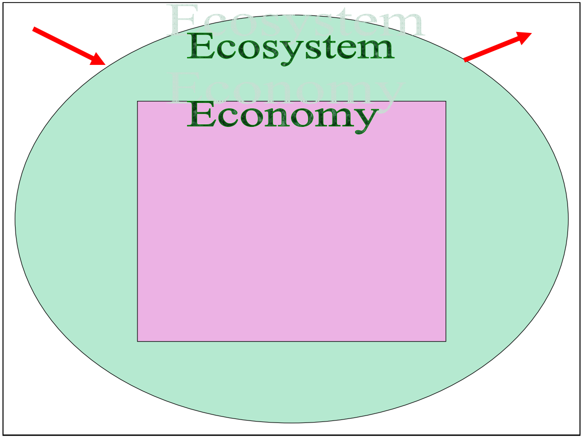
Natural Resources Engineering

Water resources engg
Bioresources engineering
Energy resources engg
Waste (resources) engg
Restoration engineering
Natural hazard engineering

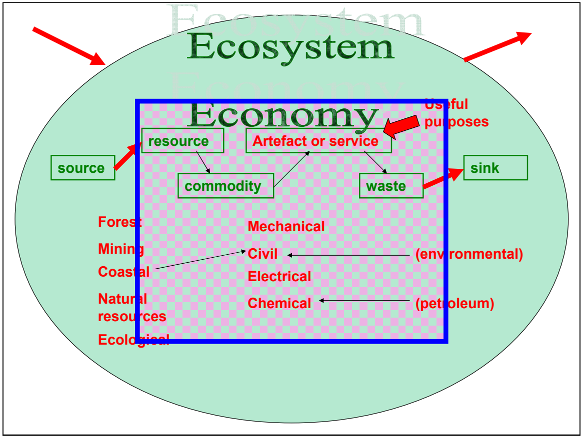
In New Zealand, as Bioresources Engineering, Agricultural Engineering became part of Natural Resources Engineering [in 1989, at Lincoln University and the University of Canterbury].



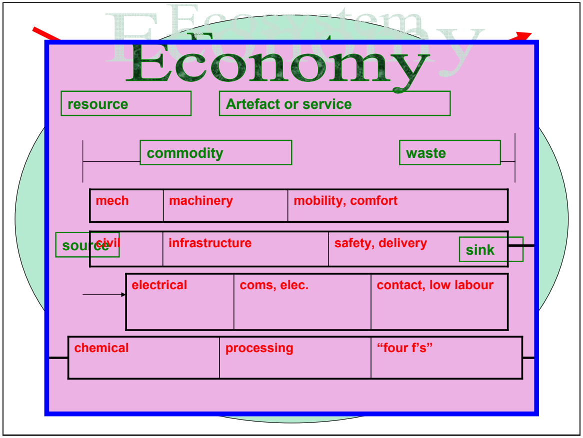
In current practice in New Zealand, Coastal Engineering is a specialisation within Civil Engineering. Petroleum Engineering is a specialisation within Chemical Engineering. Environmental Engineering is a specialisation within both Chemical and Civil Engineering. That results in four sub-disciplines of professional engineering which are carried out largely within the human economy and four sub-disciplines of professional engineering which are carried out mainly at the boundary between the human economy and Earth's ecosystem.



As mentioned much earlier, separation into ‘economy’ and ‘ecosystem’ isn’t really that simple.



In reality, there are ecosystems throughout all parts of the human economy and hardly any of Earth's ecosystem unaffected by the human economy.



Of present concern are the many signals that the human economy has outgrown our one and only planetary ecosystem – outgrown it in terms of sources and sinks. There is too much resource extraction and too much waste emission.

Sustainable Growth

It is impossible for the world economy to grow its way out of poverty and degradation … In its physical dimensions, the economy is an open subsystem of the earth's ecosystem, which is finite, non-growing and materially closed. Therefore its growth is not sustainable. The term sustainable growth when applied to the economy is a bad oxymoron – self-contradiction as prose and unevocative as poetry.

Herman E Daly, contemporary US economics professor and pioneer critic of the validity of conventional economics.

Professional engineering has been broken down here into eight sub-disciplines and many more specialisations. We have already noted that professional engineering is a "human activity which is primarily concerned with transforming sources and resources into artefacts and services by modifying mass and energy flows." Engineers have been far too successful at this activity, but insufficiently aware of their cumulative effects and the ecosystem constraints.

engineering
where ecology
meets economy

I therefore insist: (a) that the ‘engineering at the boundary’ I have emphasised here is very important and increasingly so; (b) that all engineering ‘within the economy’ needs to take responsibility for its ecosystem effects as well, both individually and cumulatively.