How to rehabilitate old oil supertankers

The enormous ships that ferry crude oil around the world embody the fossil fuel era and its legacy of pollution. But can they be transformed to be good for the environment?

By Richard Gray
1 July 2019

As you read this, around **10,420 giants are heaving** their way across the world's oceans. Their enormous metal bodies lumber onwards in spite of inclement weather and rough seas.

In their bowels, these beasts are carrying **3.8 billion barrels of crude oil between them**, enough to fuel around **418,000 transatlantic flights and for the world's cars to cover around 3 billion miles** between them. Their sticky cargo is the raw material for **billions of plastic bags, combs, trainers, drinking straws, synthetic clothing**, toys, water bottles and hundreds of other plastic-based goods that we use in our daily lives.

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There are few vessels that better symbolise the achievements and the problems of our thirst for fossil fuels than the oil tanker. Their number include some of the largest moving human-made objects on the planet – vessels of intimidating scale. Without them, our modern lives would grind to a halt. But as they chug relentlessly across the oceans, these supertankers release their own thick plumes of pollution into the atmosphere and, on occasion, into the water.

As the world moves towards more renewable energy sources and non-fossil fuel based products, there are some looking to find new jobs for oil tankers to do (Credit: Getty Images)

In a world where climate change poses a very real threat – one that could force us to wean ourselves off our fossil fuel habit – the diminishing demand for oil tankers could produce new problems. As renewable energy, bio-based plastics and other sustainable materials reduce our reliance on oil, what will we do with the gigantic vessels that currently carry it around the world?

> **There are some who believe these dirty monoliths of the oil age can be rehabilitated by transforming them into sources of clean, renewable energy**

Like most sea-going ships, they could be sent to the scrapheap, their bodies cannibalised for valuable metal that can be melted down and reused. But disposing of them is a **dirty, dangerous and poorly paid business** for those who undertake this work in some of the most deprived parts of the world.

There are some, however, who believe that these dirty monoliths of the oil age can instead be rehabilitated – they want to transform them into sources of clean, renewable energy. Engineers believe it is possible to use the vast hull of oil tankers to create floating power stations that can convert the ocean swell into electricity. This is the ambitious plan to create the world's first "waveships".

"The current problem with most wave energy projects is that they are fixed in place, close to the shore so they can be

connected to the electricity grid," says Andrew Deaner, managing director of ShipEco Marine, the **company behind the waveship project**. "This isn't necessarily where the best waves are. With a ship you are mobile, so you can move to the edge of low-pressure weather systems where the waves are bigger and there is more energy."

Transforming a supertanker into an environmentally friendly mobile power station draws on other areas of the oil industry for its inspiration. Growing up, Deaner spent a great deal of time on diving support vessels built by his father for installing and repairing oil wells and pipelines on the sea bed. These vessels have special chambers cut through their hulls, known as moon pools, which allow divers and submersible vehicles to be lowered safely into the ocean.

Oil supertankers are among the largest vessels to be built by humans but disposing of these giants at the end of their life is problematic (Credit: Getty Images)

On choppy seas, the water levels in these moon pools can move up and down as waves pass along the length of the ship. This in turn can change the air pressure inside the chamber above the pool of seawater as it rises and falls.

"It works like a giant piston," says Florent Trarieux, a renewable energy engineer who led tests on the waveship concept in scale models at Cranfield University. "We would put a turbine at the top of the chamber that is driven by the air as it is pulled back and forth by the water. We could put these in columns all down the length of a ship like an oil tanker."

While cutting holes in the bottom of a ship might not seem like the smartest move, tests by Trarieux have shown the huge displacement that oil tankers generate would help to ensure they remain buoyant. Depending on the hull size, the team believe a tanker could have a capacity to produce between 10 and 30 megawatts of electricity. A very large tanker could have up to 35 moon pools, each 20m in diameter, they say.

Laboratory tests have shown that the waveship concept is at least feasible, according to the company (Credit: ShipEco Marine)

The technology needed to do this is far from pie-in-the-sky. In the 1970s the Japan Marine Science and Technology Center built **a boat shaped buoy that used air turbines** at the top of 22 bottomless chambers cut into the hull. But tests of the vessel, which was anchored in the Sea of Japan, showed its ability to **absorb energy from the waves was "disappointing"**.

More recently, however, engineering giants Siemens have developed a more efficient **"hydroair" turbine** that can turn the oscillating flow of air inside a water filled chamber into electricity. Another firm, called Ocean Energy, has also **built buoys that use a similar principle** that are being tested in the Atlantic Ocean.

Like many other wave energy devices, these systems are mounted on platforms that are moored in place and so rely upon the weather at a single spot in the ocean to generate sufficient waves. Wave energy generators also need to be able to transmit the electricity they produce back to shore, and so need to be close to the coast so they can be connected through cables.

> **Putting oscillating air flow turbines above moon pools on board ships could allow them to chase storms around the oceans to get the best waves**

Deaner and Trarieux, however, believe this is limiting the potential of wave power. They say that putting oscillating air flow turbines above moon pools on board ships could allow them to chase storms around the oceans to get the best waves.

"Effectively we would be going 'fishing for energy'," says Trarieux. Out on the open ocean where unimpeded winds can generate larger waves, the **amount of energy that can be generated is many times greater** than can be produced in coastal areas. "It is a completely different approach to wave energy."

Dozens of moon pools could be cut into the hull of a repurposed oil tanker to turn it into a mobile power station (Credit: ShipEco Marine)

The project has already received the backing of the UK government, which **funded some of the feasibility studies** and scale model tests. These have shown that the tankers can be modified to create moon pools without compromising their strength and stability, according to Trarieux.

The next challenge is getting hold of a suitable ship. Second-hand oil tankers are not cheap and even an ageing, relatively small ship **can cost millions of dollars on the open market**. But the team believe the prevailing wind could work in their favour as the world moves away from using fossil fuels.

> **All that steel could be cut up and reused, or we could repurpose them to make wave energy – Florent Trarieux**

“There are thousands of oil tankers currently in operation and hundreds reaching the end of their service lives every year,” says Trarieux. “All that steel could be cut up and reused, or we could repurpose them to make wave energy.”

The number of large oil tankers being **scrapped reached record levels in 2018**, with more than 100 vessels being sent for demolition. The **majority ended up on beaches in Bangladesh, India and Pakistan** where they are taken apart by unskilled workers, often with little or no safety equipment. The life expectancy of those **doing this dangerous work at these enormous shipbreaking yards** has been estimated to be **20 years lower than the general population** in these countries and the industry has faced **accusations of human rights abuses**. Environmental campaigners have also raised concerns about the **hazardous substances and pollutants that leach out** from the ships as they are dismantled, which has led to **calls for stricter environmental regulations around ship breaking**.

Oil tankers sent for scrapping are often run aground on beaches in Bangladesh where they are dismantled by hand by poorly paid unskilled workers (Credit: Getty Images)

Converting these vessels into waveships could be a tempting alternative to scrapping them. “Transforming old oil tankers, used to ship millions of gallons of oil around the world, into a potential clean energy source is yet another example of the UK leading the global shift to clean growth,” says Claire Perry, energy and clean growth minister in the UK.

> **If someone wanted to put a chocolate factory on the deck of our waveship we could actually be manufacturing products as it is being shipped to markets around the world – Andrew Deaner**

But Deaner’s vision goes beyond simply turning them into power stations where the energy will be stored on board in expensive, heavy batteries. Instead, he sees these giant ships becoming floating, self-sustainable factories by putting the electricity they produce to immediate use.

“We are looking at making products onboard so we are not tied to any electricity grid connection,” he says. “We are looking at producing fresh water – we think we could make somewhere between 18,000 and 36,000 tonnes a day before bringing it ashore. We could also make hydrogen or liquid nitrogen, which we could sell to industry.

“But if someone wanted to put a chocolate factory on the deck of our waveship we could actually be manufacturing products as it is being shipped to markets around the world.”

Their vast size could allow supertankers to be turned into iconic shoreside public buildings (Credit: Chris Collaris Design)

But not everyone is convinced by the idea. Stephen Salter, a leading wave energy expert at the University of Edinburgh who invented one of the early wave energy devices commonly known as **Salter's Duck**, says air turbines may struggle to cope with the wide range of flow speeds caused by natural waves on the ocean. He also worries about how resilient an oil tanker would be on the high seas with holes cut in its hull.

"Cutting a round hole raises stress by a factor of three," he says. "If the tanker designer did a good job, then a great deal of modification will be needed. Any sharp corners will also dissipate lots of energy."

But there could be some alternative uses for the world's discarded oil tankers. One New York-based artist recently proposed **tipping a 300-metre-long supertanker on its end** and anchoring it vertically in a harbour as a visual reminder of the need for mankind to end the fossil fuel era.

A group of Dutch architects have also proposed **turning old supertankers into floating public villages** that contain shopping malls, concert venues, museums, swimming pools and a public park on the top deck. But the firm behind the concept, Chris Collaris Design, say they have yet to find anyone brave enough to take the concept further.

Thousands of tankers are responsible for transporting crude oil around the world so it can be refined into fuel and hundreds of other products (Credit: Getty Images)

But anchoring an oil tanker in such a way that it can be safely boarded and used by thousands of people is a tricky problem. Others believe it may be better to turn these enormous steel beasts into something that provides services to people rather than being somewhere they can meet and gather.

A Norwegian company called EnviroNor is developing technology it hopes can be used to convert oil tankers into **mobile waste water treatment plants**. These offshore treatment plants could then be sent to cities around the world that are struggling with water shortages. EnviroNor say a single tanker could **treat the waste water from a city of 250,000 inhabitants**. Mooring these converted tankers alongside wind farms, they could also use renewable energy to desalinate water for coastal cities.

> **Since 1985, 39 tankers of various sorts have been sunk off the coast of the US and one off the coast of Malta**

But one of the most common current uses for old oil tankers after scrapping is perhaps also the most surprising – turning them into wildlife havens. Oil tankers are more commonly associated with harming marine life due to spills after accidents, but at least 40 of these vessels have been deliberately sunk to create artificial underwater reefs.

“If they are cleaned properly, oil tankers have a very big surface for things to attach to underwater and they will have a long lifespan,” says Dalia Conde, director of science at Species 360, an international conservation research organisation, who recently created **a global database of ships that have been deliberately wrecked to create artificial reefs**. “There is the potential to attract a lot of fish, molluscs, different seaweeds.”

Underwater wrecks of oil supertankers like the Amoco Milford Haven that sank off the coast of Italy in 1991 can become havens for marine life (Credit: Alamy)

Cleaning up an oil tanker is an expensive business, though – it can **cost several million dollars** to mop up all the toxic mess that accumulates in these vessels. But since 1985, 39 tankers of various sorts have been sunk off the coast of the US and one off the coast of Malta. Unfortunately, little work has been done to monitor the impact these vessels have had on the ocean environments where they were sunk.

Anecdotal reports from divers who have visited some of these tankers, however, suggests they host a rich diversity of life including lobsters, shellfish, **barracuda and sharks**. The wreck of the supertanker MT Haven, which sank off the coast of Genoa, Italy after an explosion on board in 1991 has also become a popular diver site. Although 40,000 tons of oil poured into the sea in the accident, it has since become **home to a wide array of marine animals**.

“It is surprising that so many of these ships have been deliberately sunk to provide habitats for fish,” says Conde. “But we need to start monitoring these sites properly. With the crisis we are facing in our oceans and climate, it would be good if there was a way of using ships like oil tankers to do some good.”

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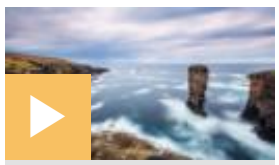

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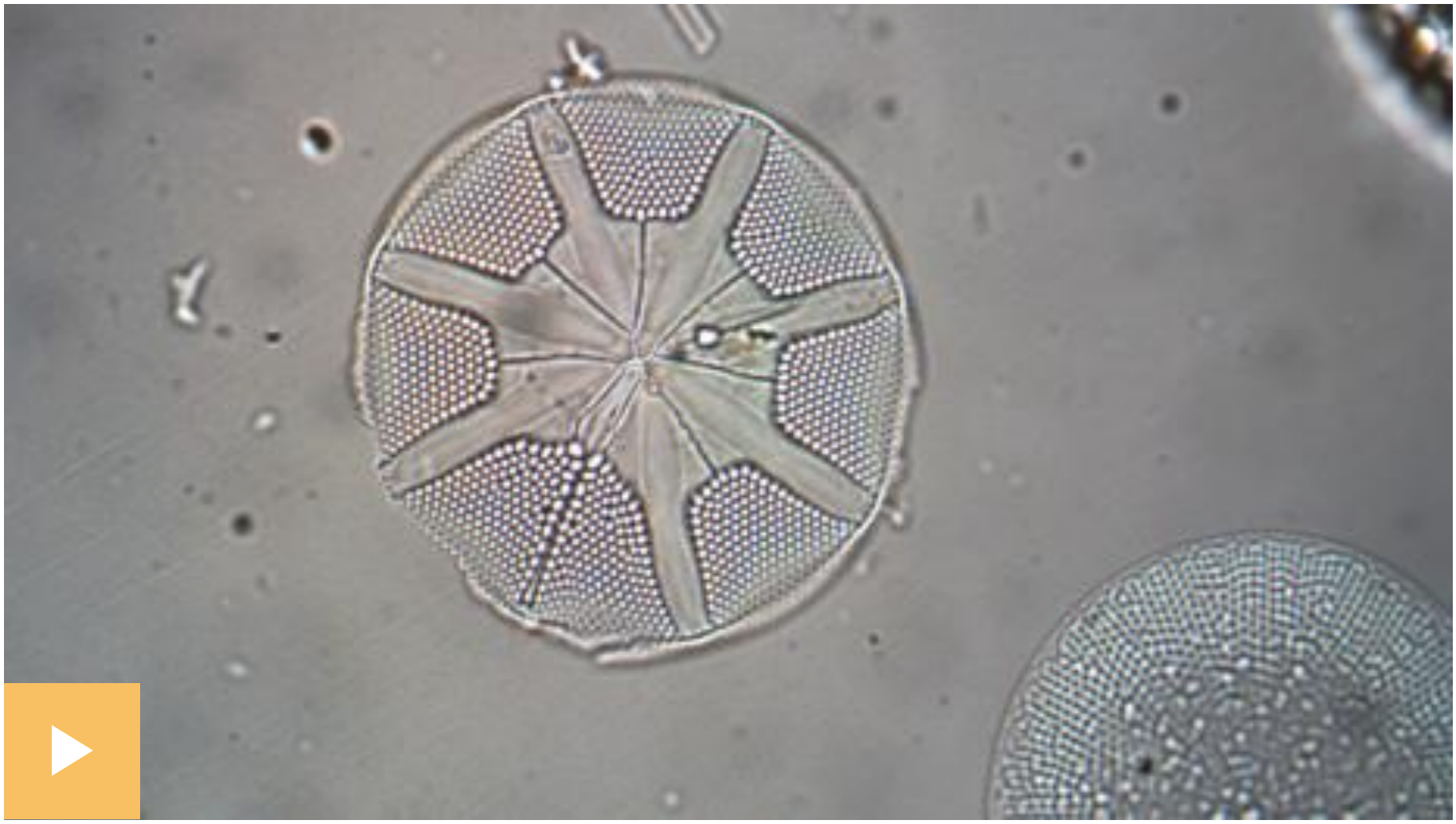

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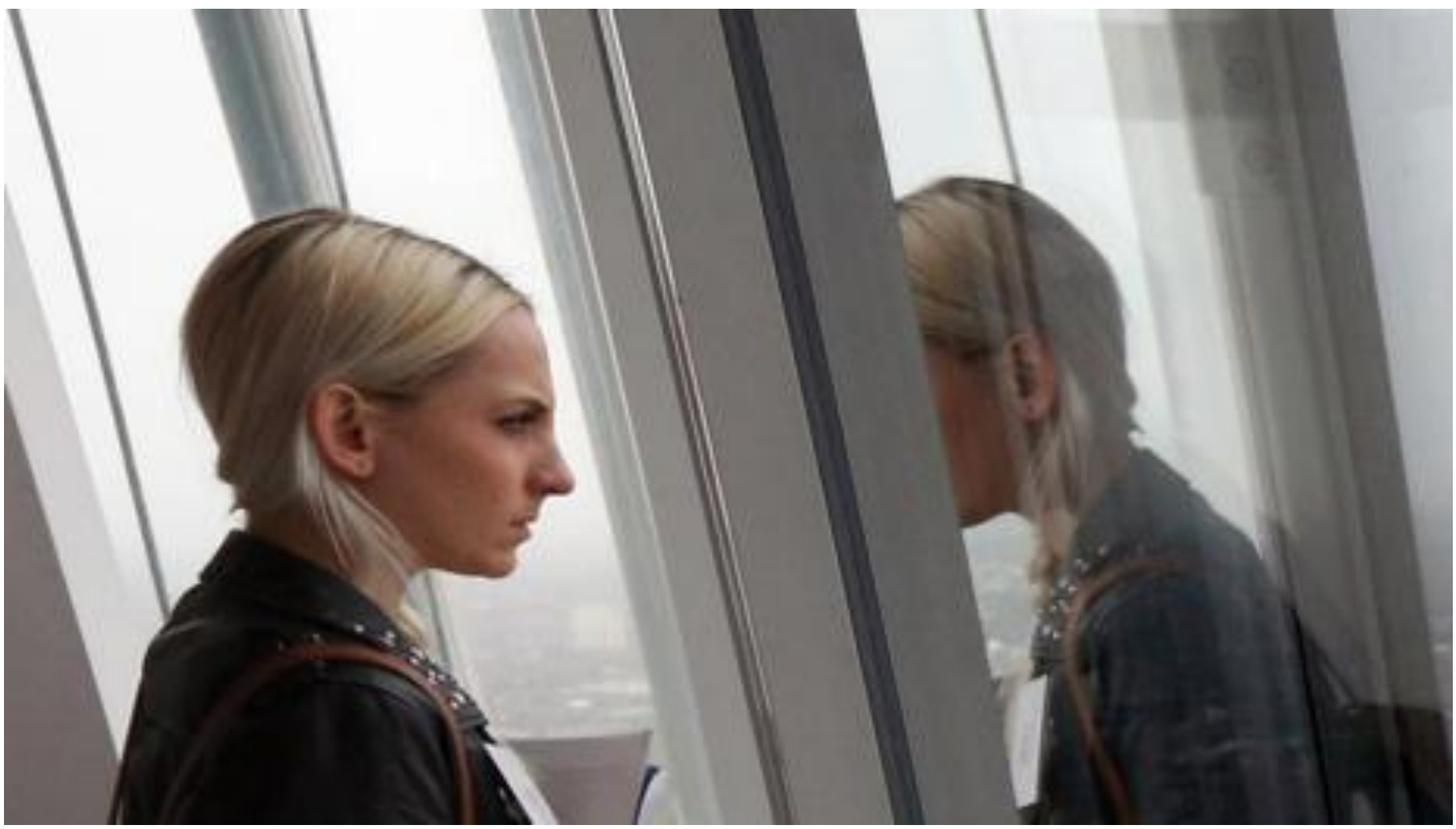

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The maths problem that could bring the world to a halt

Our hectic, on-demand lifestyles rely upon allocating finite sets of resources to constantly changing numbers of people. As this task grows ever harder, it will require solutions to a little-known mathematical riddle.

By Gemma Church

9 June 2019

futurenow

It’s not easy to accurately predict what humans want and when they will want it. We’re demanding creatures, expecting the world to deliver speedy solutions to our increasingly complex and diverse modern-day problems.

Over the last few decades, researchers have developed a range of pretty effective mathematical solutions that can allocate resources across a variety of industries and scenarios so they can attempt to keep up with the daily demands our lives place on them. But when an allocation made at one time affects subsequent allocations, the problem becomes dynamic, and the passing of time must be considered as part of the equation. This throws a mathematical spanner in the works, requiring these solutions to now take into account the changing and uncertain nature of the real world.

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Such problems are collectively known as dynamic resource allocation problems. They crop up anywhere you find a limited resource that needs to be assigned in real time.

Whether you're waiting for a taxi or a next-day delivery, the list of dynamic resource allocation problems and their everyday applications is "almost endless" according to Warren Powell, an engineer at Princeton University who has been investigating these problems since the 1980s.

Anywhere that has limited resources but a high level of constantly changing demand will face dynamic resource allocation problems of one sort or another (Credit: Getty Images)

But dynamic resource allocation problems are not just concerned with giving humans what they want, when they want it. They will also be essential for tackling some of the world's most fundamental and complex issues, including climate change, as they help us allocate our planet's often scarce and depleted resources in the most efficient ways possible.

But let's first look at a simplified example to see what a dynamic resource allocation problem is and what makes it so difficult to solve.

Imagine you're cooking a roast dinner for your family of four. You opt for beef with all the trimmings, safe in the knowledge that it's a firm family favourite. But just as you're about to serve up, your daughter announces she's vegetarian, your partner texts to say they're running late, and your son tells you he's invited "a few" friends over for dinner too. Then, your dog runs off with the joint of beef while you're desperately trying to work out how you are going to meet the needs of all these (quite frankly) very demanding and unruly individuals.

> **They will be essential for tackling some of the world's most fundamental and complex issues, including climate change**

This is a trivial example of a dynamic resource allocation problem, but it demonstrates some of the core challenges researchers face when tackling these problems. For starters, the parameters affecting demand change unexpectedly both in the short and long term. There's no way you could have accurately predicted your daughter's new dietary requirements, your partner's tardy arrival or your son's additional guests as you were prepping this meal.

In the longer term, demand for meals in your house also changes on a day-to-day basis. You may need to feed two or 20 people at each sitting. From meal to meal, you have no idea who'll want feeding, what they will want or when they will want it. You can take an educated guess based on prior experience, but this is not a robust method because human nature and the many other parameters affecting demand are unpredictable.

Next day delivery has become something many of us take for granted now, but ensuring this can be done efficiently is a complex problem (Credit: Getty Images)

The actions of the individuals in this scenario also affect the future state of the system. Every time you allocate a specific meal to a person, this changes the system. It removes both one hungry person and food from your kitchen.

"All [dynamic resource allocation] examples need to deal with changing inputs and environments, which are highly dynamic and difficult to estimate and predict, as the future load is not statistically dependent on the current load," says Eiko Yoneki, a senior researcher leading the data centric systems group at the University of Cambridge's Computer Laboratory. "One change triggers another change, and if you want to control the system with accurate decisions, one must consider the future status of the system."

What's more, as more people or meal options come into your kitchen, things are complicated further. You now have more ways to allocate a range of different meals to different people. This number of combinations scales exponentially as you add more people or meals to the system.

This is exactly what a large hospital may face, for example, when trying to feed all the patients coming through its doors. The same applies when trying to treat these patients. The medicines they require, which themselves have a limited shelf life, and the equipment needed for diagnosis and treatment will change constantly as different patients arrive. Limited resources like MRI scanners, doctors and nurses need to be allocated too. To address this, and prevent costs from soaring out of control, the hospital management might deploy mathematical models to help coordinate all these things.

A busy hospital kitchen deals with constantly changing demands that make it difficult to predict how many patients it has to feed and with what (Credit: Science Photo Library)

The trouble is that most existing methods rely on historical data to make predictions. This method doesn't scale very well for such systems and can't cope with even the smallest changes. If a change does occur, they go back to square one and start working out a solution all over again. Such problems quickly become computationally intractable, even for a fairly small number of people and resources – whether that's a meal or an MRI scanner.

Dynamic resource allocation problems also arise from a range of different scenarios and each one has its own specific issues. For example, Yoneki is investigating the implications of these problems to help our computer systems and applications run faster and more efficiently.

"Modern computer systems are complex, and many configuration parameters need to be tuned, including resource allocation such as memory, computation capacity, communication capability, and any input to the systems," she says. "Computer systems are dynamic and deal with ever-changing environments, which requires dynamic control methodology."

> **Mobile phone networks and cloud computing are reliant upon solving these problems too**

So, the computer you are reading this article on is almost certainly wrestling with some dynamic resource allocation issues at this very moment. **Mobile phone networks** and **cloud computing** are reliant upon solving these problems too.

Delivery firms are also tackling dynamic resource allocation problems to speed up deliveries. For example, UPS developed its On-Road Integrated Optimisation and Navigation (Orion) system to optimise its delivery routes using advanced algorithms. The company claims the solution has saved it 100 million miles per year – but **other reports** reveal the system struggles in complex urban environments.

Supply chains are another "problem that is never going to go away", says Powell, because of the complex nature of today's products. For example, if you want to manufacture a standard smartphone you need to coordinate hundreds

of components from around the globe, all of which are brought together in a specific order on the factory floor. “Supply chain disruptions are a major problem when trying to meet the needs of society,” he adds.

Mobile phone networks need to allocate resources like bandwidth and energy, as well as whether downloads or calls get priority (Credit: Getty Images)

Our energy supplies are also increasingly complex, relying on unpredictable renewables such as wind and solar. The outputs of these sources can fluctuate wildly, as can demand for energy at any given time. The cost of energy can fluctuate too – electricity prices can spike up to 50 times their average within a five-minute period.

In truth, you will struggle to find an industry that doesn’t faces the challenges of managing a dynamic resource allocation problem in one form or another. “Electricity prices, yield of parts in a supply chain, travel times, equipment failures, and the behaviour of people are all issues I have had to deal with,” says Powell. “This problem is so rich that there are at least 15 distinct research communities working on this problem from different perspectives.”

This is an important point. The diversity of dynamic resource allocation problems means there needs to be industry-wide standardisation of the different computational techniques and methods used to tackle it. Powell is one of those attempting to bring together the disparate communities working on dynamic resource allocation problems. “Our approach does not replace any prior work,” he says. “Rather, it brings all of this work together and helps to identify opportunities for cross-fertilisation.”

> **Advances in machine learning are offering new hopes of tackling dynamic resource allocation problems**

A rich set of operational management tools have been highly effective over the last few decades to address dynamic resource allocation problems, helping the world’s airlines, logistics firms and road networks increase their performance in a range of ways. However, “high dimensionality” – where many different parametres need to be taken into account – and uncertainty “remains a challenge”, according to Powell.

Advances in machine learning are offering new hopes of tackling dynamic resource allocation problems. An artificial intelligence technique called deep reinforcement learning allows an algorithm to learn what to do by interacting with

the environment. The algorithm is designed to learn without human intervention by being rewarded for performing correctly and penalised for performing incorrectly. By attempting to maximise rewards and minimise penalties, it can quickly reach an optimal state.

Deep reinforcement learning recently enabled the AlphaGo program from Google's DeepMind to defeat the world champion in Go. The system started off knowing nothing about the game of Go, then played against itself to train and optimise its performance. While games are an important proof of concept for deep reinforcement learning techniques, learning how to play games is not the end goal for such methods.

Rerouting traffic on busy roads to avoid jams is currently a challenge for even the most advanced algorithms of today (Credit: Getty Images)

Yoneki and her team have been working on providing a viable alternative to human-generated heuristics for performance tuning in computer systems using deep reinforcement learning. The computer system they have been developing can scale to solve decision-making problems that were previously computationally intractable. It addresses the issue of computational complexity and can also respond to changing parameters in real time.

Systems employing this approach have already been used to optimise system performance in areas including resource management, device payment optimisation and data centre cooling. "Such applications are just at the beginning and open up a whole new world of opportunities," says Yoneki.

A team of researchers at an artificial intelligence startup called Prowler.io, based in Cambridge in the UK, is also using its own machine learning approach to tackle dynamic resource allocation problems. Its algorithms provide incentives to induce a specific behaviour in the system. In a real-world context, this could be equivalent to introducing smart tolls to incentivise drivers to use specific roads and minimise traffic congestion and pollution.

> **As our populations continue to grow and our hunger for on-demand services increases, the complexity of dynamic resource allocation problems will only**

intensify

But there is still much work to be done in the machine learning field, says Yoneki.

“Use of reinforcement learning will move dynamic resource allocation problems forward, but it requires a lot of data to build a reinforcement learning model, and it is still at an experimental stage, especially computer systems where more complex parameters have to be dealt with than simple game cases,” she says. “The research on this topic is rapidly progressing.”

We’re still some way off cracking this unique set of problems as today’s techniques and computational resources quickly run out of steam when we try to tackle the complexity and random nature of the real world. But as our populations continue to grow and our hunger for on-demand services increases, the complexity of dynamic resource allocation problems and their impact on our day-to-day lives will only intensify.

And if we don’t start to address dynamic resource allocation problems now, we won't just struggle to get dinner on the table – the entire world could grind to a halt.

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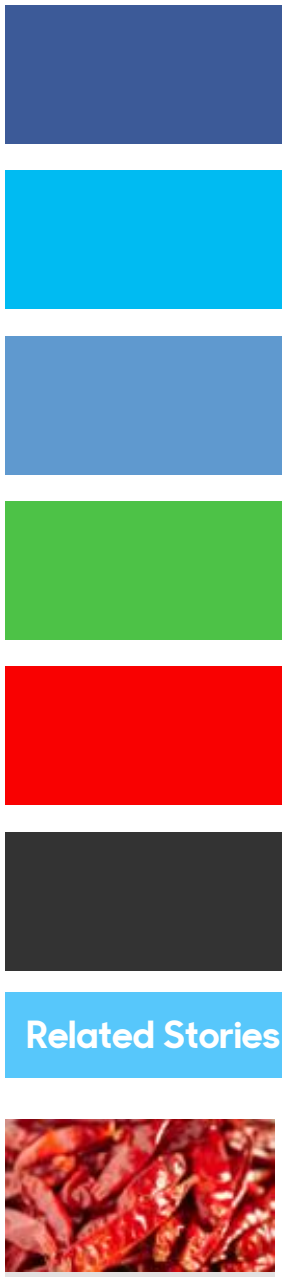

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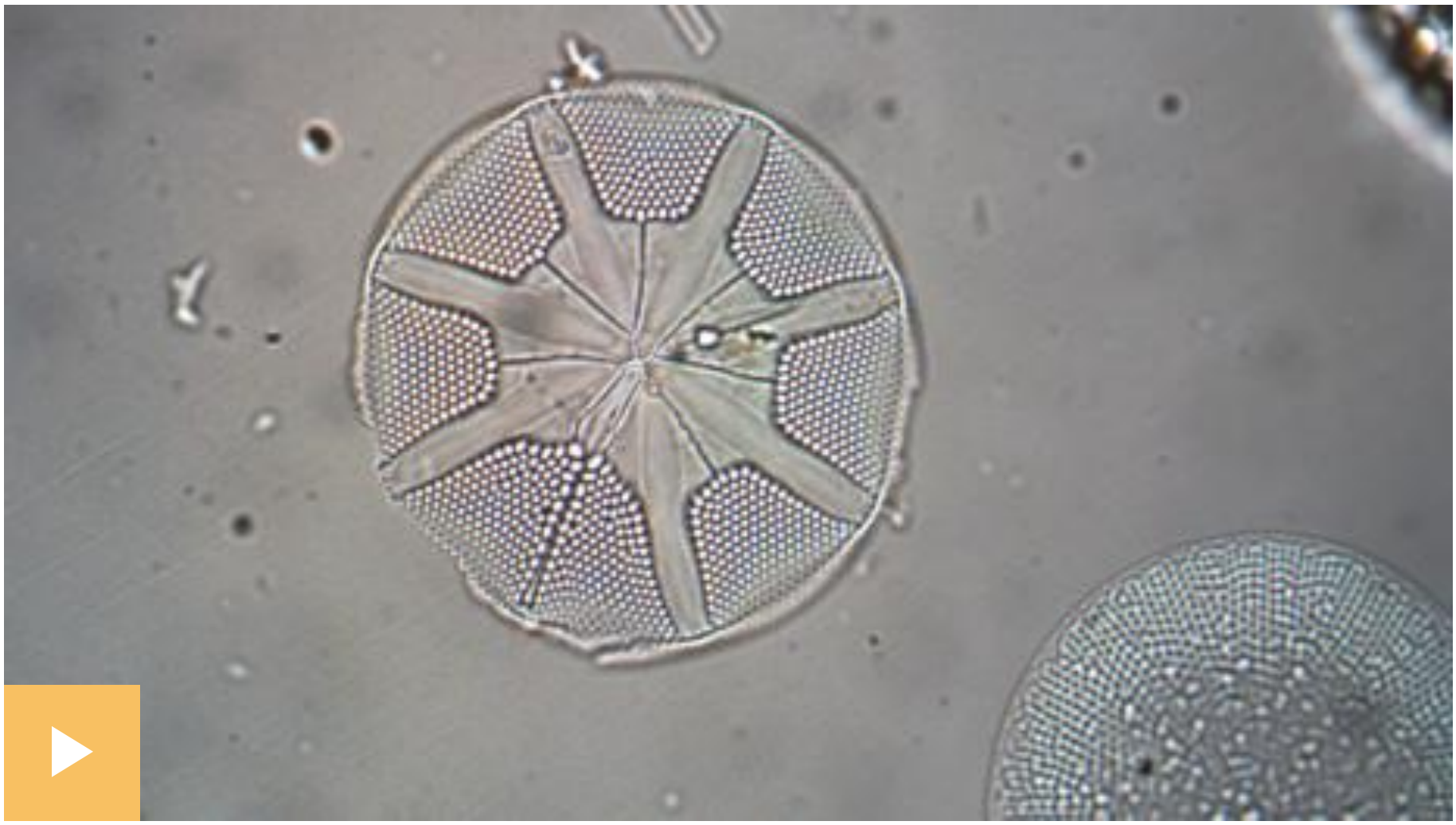

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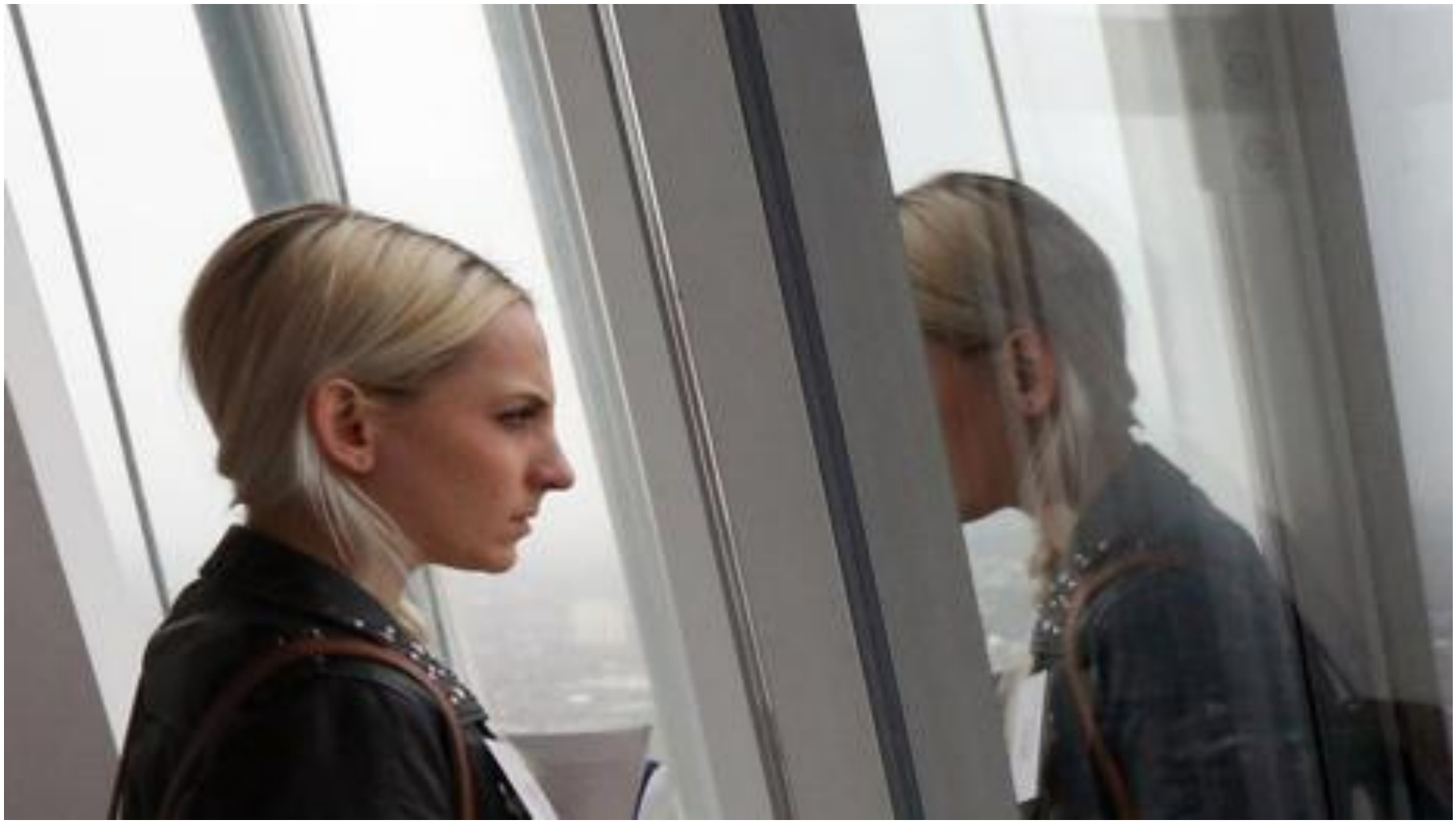

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