Weird and wonderful: The next wave of renewable energy innovation

As global pressures to decarbonize mounts, the renewable energy sector continues to push boundaries. The sector is going beyond established technologies such as solar, wind and biofuels, with increasingly inventive solutions that blur the lines between science fiction and scalable infrastructure.

Insurers supporting their client's diversification must be prepared to engage with these emerging technologies. With their novelty, will come insurability challenges, but as confidence builds and experience generates reliable performance data, insurers will be able to consider broader levels of risk transfer.

Key takeaways:

- Innovation continues at pace across the renewables sector, with kinetic infrastructure, solar-integrated materials, nuclear fusion and gravity-based storage all developing as potential technologies
- The insurance market will need to evolve in parallel to enable safe experimentation and scalable deployment in this fast-moving sector
- For technology developers, building a robust risk management strategy will need to account for agility as the risks associated with new technologies come to the fore

In recent months and years, new and exciting renewable energy innovation has accelerated across the globe.

Road-powered charging could accelerate growth in electric vehicles

Sweden has repurposed an existing black tarmac road to a permanent electrified road – the first of its kind in the world.[1] On this road, cars and trucks can recharge while driving. Considering that the required energy density (related to size/weight) of batteries is a barrier to commercial trucks being electrically powered, this innovation is a major breakthrough.

Charging on-the-go means vehicles can travel for longer distances with smaller batteries without needing to wait at charging stations. E-roads eliminate the key challenges of electric vehicles, such as charge time and distance limitation, which could make electric vehicles a more feasible option for drivers.

In Sweden, charging technology that powers electrified roads can take two primary forms:

1. **Conductive charging:** This method requires the vehicle to make physical contact with an electrified rail or overhead wire. For example, the eRoad Arlanda pilot project near Stockholm has a two-kilometre rail that charges trucks using a retractable arm.[2] When a truck drives over the rail, the arm lowers and connects, providing up to 200kW of power. This is enough to support long-distance freight transport. While this method is energy-efficient, it needs precise alignment and special lanes, including vehicle compatibility with other countries.

2. **Inductive charging:** This system uses coils placed under the road surface to create electromagnetic fields. Vehicles with receiver coils can turn this energy into electricity, charging their batteries without wires. Sweden tested this technology on Gotland Island, where electric buses and trucks charged while driving along a 2.5-mile section[3]. Although inductive charging reduces wear and tear, it provides less power and faces issues with energy loss and the same alignment and compatibility issues as conductive charging.

The challenge: Insurance markets are being pressured to build renewable energy into their portfolios, but prototypicality of innovative technologies such as road-powered charging or 'e-roads' is a major challenge. The susceptibility to damage is largely unknown, and property markets will require robust risk data to make informed decisions about building these risks into portfolios.

Piezoelectric roadways could move the dial on energy usage

Research from Rutgers CAIT explores the use of piezoelectric materials to generate electricity from roadways.[4] These roadways harness the impact and stress from traffic alongside other sources of energy, such as solar, thermal and geothermal, to create a sustainable infrastructure model.

Similarly, kinetic pavements convert footsteps into electrical energy. These systems are ideal for stadiums, transit hubs, or high-footfall areas and offer off-grid power for lighting, signage, or small electronics.

The challenge: Though output remains modest, insurers must assess risks related to wear-and-tear, water ingress and injury liability on modified surfaces.

Gravity storage systems can take on the heavy lifting

Emerging gravity storage systems lift heavy blocks (or trains on inclined tracks) during times of excess power and release them to generate electricity when needed. These systems, such as those trialed in Switzerland and the U.S., offer mechanical, long-duration storage without chemical degradation.

Grid-scale energy storage solutions are designed to capture the kinetic energy produced by lifting and dropping masses. These masses are usually made from locally sourced or recycled materials to support sustainability. Gravity does the work as lowering weights releases stored energy.

The challenge: A major challenge is the loss of energy as byproducts during conversions to gravitational pull and back. Losses including heat dissipation and mechanical friction can lead to efficiencies below 70%,

and geographical constraints can also limit scalability.[5] With high initial costs and environmental impacts from construction and material sourcing, getting projects off the ground and managing risks are barriers to growth for gravity storage technologies.

Bladder-based ocean energy moves with the tides

On the marine frontier, engineers are trialing inflatable 'bladder' devices that float under the surface and mimic the movement of sea creatures. These flexible structures absorb wave energy as they contract and expand, converting kinetic motion into hydraulic power. Unlike rigid tidal turbines, these devices are less vulnerable to storm damage and marine corrosion.

The challenge: Structural integrity and energy yield remain key concerns for insurers and investors. Unknown risks to property damage and associated environmental damage need to be carefully modeled and mitigated.

Fungi-powered bioenergy is shining a light on micro-energy solutions

Researchers are exploring the bioelectric properties of mycelium, the root network of fungi. Some species naturally produce small voltages as they decompose organic matter. Biotech start-up companies are experimenting with mycelium-based bio-batteries that could offer low-impact, biodegradable power sources for sensors and small electronics. While still in its infancy, this area exemplifies the creative thinking behind sustainable micro-energy solutions.

The challenge: Aside from technical challenges, proprietary needs and scientific knowledge gaps, bioelectric solutions are perceived as prototypical by the insurance markets, and the technology will need to prove to be commercially scalable with robust engineering and analytical models before they can be built into portfolios.

Solar windows are a bright idea for urban areas

Using the concept of building-integrated photovoltaics (BIPV), solar windows are windows with solar panels that absorb ultraviolet and infrared light and convert them into electricity. These dual-purpose materials reduce building energy demand and could be a solution in urban environments. According to a leading manufacturer, solar windows are typically 30% more expensive than conventional windows[6]. But this is compensated considering the yearly reduction in utility bills and the decrease in global emissions.

The challenge: Solar windows present novel risks relating to visibility distortion, performance degradation and integration into existing facades.

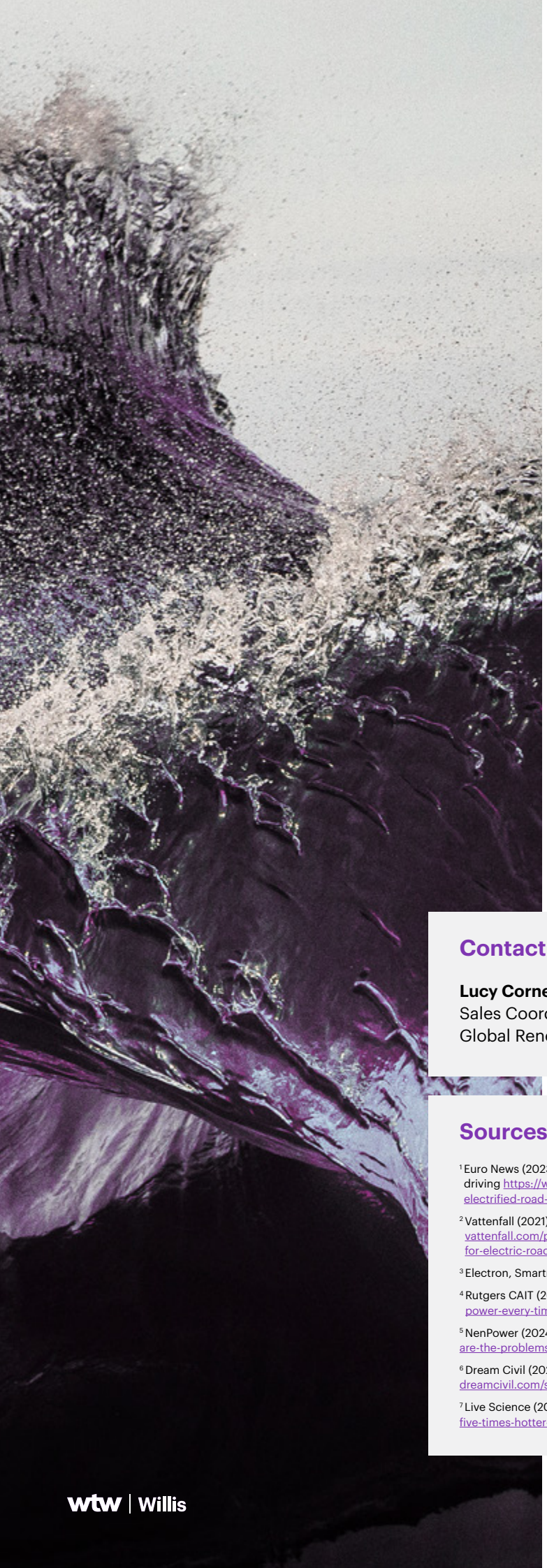
Magnitudes of innovation in quick-concept fission and China's artificial sun

Alongside modular fission reactors, global focus is intensifying on nuclear fusion. In its quest to make clean, limitless energy a reality, China's artificial sun project has achieved record temperatures, which are five-times hotter than the core of the sun.[7]

The challenge: While commercial viability is years away, fusion technology brings new frontiers of risk, including high-energy magnetic confinement, tritium handling and long-term containment planning. Insurers will need to prepare for entirely new frameworks around liability, regulation and performance coverages.

What innovation means for the renewable energy insurance market

As renewable energy technologies evolve rapidly, the insurance market needs to keep pace. Traditional underwriting frameworks may fall short when applied to unproven systems with limited operational history, complex interdependencies, or hybrid functions (e.g. energy generation and structural utility). Insurers need to invest in technical expertise, flexible policy structures, and collaborative risk modeling to assess performance uncertainty, liability pathways, cyber exposure and regulatory alignment. Risk engineering will have a major role in helping insurers identify which elements of new technology projects are entirely prototypical, and which elements have roots in existing and known risks. With these



in-depth insights, both markets and renewable energy companies will be in a position to move forward with a shared understanding for sound decision-making. Proactive engagement with innovators, regulators and clients will be essential to ensure that insurance products are not only fit for purpose, but also enable safe experimentation and scalable deployment in this fast-moving sector.

Opportunities in renewable energy technologies are there for the taking

As these weird and wonderful technologies move from concept to pilot phase, they bring with them a host of challenges: mechanical reliability; long-term degradation; unpredictable yield; and lack of performance benchmarks. All these challenges complicate traditional actuarial models. But risk also brings opportunity. Innovations in renewable energy technologies represent exciting new classes of insurable assets for early movers in the renewable energy insurance market.

For insurers, the message is clear. The future of renewable energy won't just be wind and sun, it will be the road, the sea, the soil beneath us and even the fungi underfoot.

Being an early mover will be high risk but could be high reward. For forward-thinking renewable energy companies, a robust risk management strategy will need to account for agility as the risks associated with new technologies come to the fore, and insurance market dynamics respond. The role of a broker will be critical in enabling insurers to understand the risks, backed by data, and collaborate on building solutions to drive the clean energy transition forward.

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This update analyses our observations of the current global market conditions for renewable energy insurance and the impact this has on insurance buyers. This update is based on our observations of the market for our WTW clients and is not a whole of market review.

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