

From ambition to reality

Weaving the threads of net-zero delivery

Translating pathways to reality

In this groundbreaking paper, Worley and Princeton University's Andlinger Center for Energy and the Environment explore the practical shifts required to successfully develop and deliver the energy infrastructure needed to achieve mid-century net-zero targets.

The collaboration was formalized through Princeton E-affiliates Partnership, a corporate membership program administered by Princeton University's Andlinger Center for Energy and the Environment. The program enables corporations to pursue transformational innovations in energy and the environment in close collaboration with academic experts.

Drawing on research and analysis in Princeton's Net-Zero America study, it is apparent that achieving net zero is technically feasible and affordable.

However, to do so is an immense infrastructure delivery challenge – unprecedented in global terms – which will require businesses and governments to transform how they engage communities and develop and deliver projects.

The focus of the paper is on supply-side energy infrastructure, to explore five key shifts in thinking needed to deliver a net-zero transition.

The paper will help you understand the scale of the task, and then take you through each of these shifts. The combination of all five shifts is how we can go about making net zero a reality.

This paper is a must read for decision-makers in government, industry and the broader community. It illuminates the significant delivery challenges that we face and outlines key shifts needed to transform project delivery to enable the necessary changes.



Shift 1: Broaden how value is defined

We need to consider whether our projects deliver social and environmental value, in addition to financial value. We also need to share a project's value – money, jobs, clean environments – amongst all stakeholders. To broaden what value means, we need to:

- **Strengthen human capacity.** Make the energy sector a more attractive employer.
- **Invest with foresight.** Invest in technological options and earmark land we'll need over coming years in the transition.
- **Increase system redundancy.** Strengthen resiliency in electrical infrastructure, assure grid reliability and protect against cyber-attacks.
- **Nurture people's trust.** Involve people who'll be impacted by the energy infrastructure or transition in the planning and development process.
- **Accelerate approval and regulatory processes.** Be transparent, so that people trust in the governance processes.

Shift 2: Keep our technology options open

Net zero requires a tapestry of different technology approaches, working within resource, geographic, market, and enviro-socio-political constraints. All technologies will have their own advantages as well as constraints, making them more or less suitable in different situations.

We need to develop all possible decarbonization technologies, spreading our effort and investment broadly. This gives the best chance of enabling future solutions.

We must start the transition now, with the low-carbon technologies we already have – such as wind and solar – while investing in those still emerging, like hydrogen and direct air capture.

Shift 3: Design one, build many

We must standardize as many aspects of a project's design as possible, and then replicate that design many times. We must also develop projects in parallel. The execution of large programs of projects will streamline all steps in the development sequence.

This approach will:

- **Save time.** Cut down engineering effort and time taken for regulatory approvals. Multiple projects being built at once will dramatically compress schedules.
- **Optimize resources.** Use the transition to distribute job opportunities more evenly and equitably, across regions.
- **Speed up the supply chain.** By introducing common equipment standards across countries, equipment will be quicker to make, transport and install. This will enable establishment of local supply chains.

Shift 4: Communicate and collaborate

Countries, policy makers, industry and communities will need to communicate and collaborate like never before. To enable this mutual respect, trust, clarity, and well-defined roles and expectations will be required.

We will need to share information more openly. Government master plans must keep communities at the center of their development plans. Industry must work with all and share risks, ideas, patents, processes and designs, using innovative contracts with transparent, auditable margins.

We need to form coalitions, empowered to hit net-zero targets and deliver value. Value in financial terms. In job creation. And in clean environments.

Shift 5: Enable and monitor digitally

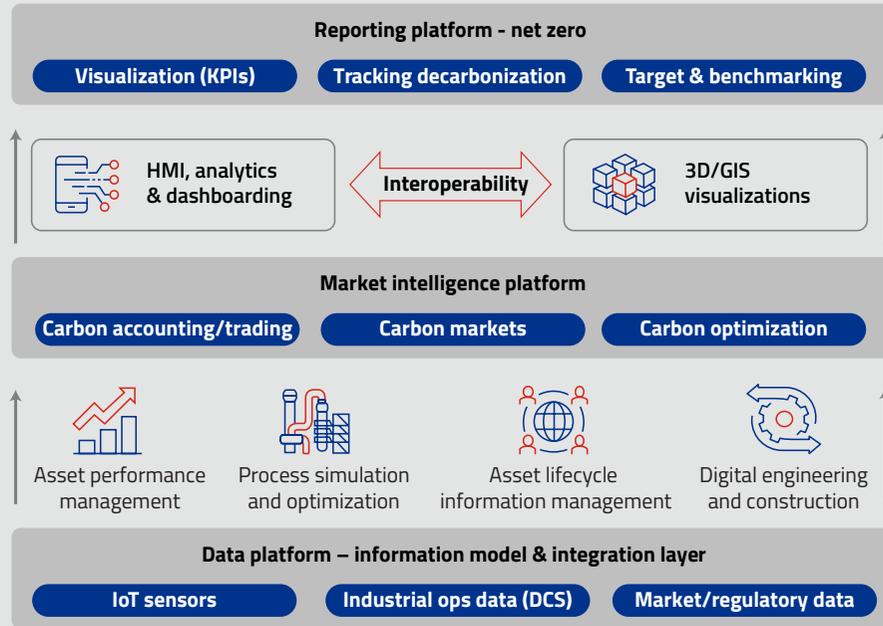
Digital is key to accelerating the net-zero transition in a way that ensures transparency, trust and shared value.

Using digital technology, we can visualize the impact of a project, and track its performance once it's up and running. We'll encourage public scrutiny and, consequently, public trust.

We envisage a Net-Zero Enablement Platform, which builds on Princeton's six decarbonization pillars and has three distinct levels, shown in the figure on the next page.



A net-zero enablement platform



Reporting platform - net zero

Visualization (KPIs) Tracking decarbonization Target & benchmarking

Market intelligence platform

Carbon accounting/trading Carbon markets Carbon optimization

Data platform - information model & integration layer

IoT sensors Industrial ops data (DCS) Market/regulatory data

HMI, analytics & dashboarding Interoperability 3D/GIS visualizations

Asset performance management Process simulation and optimization Asset lifecycle information management Digital engineering and construction

- IoT sensors
- Smart meters
- Artificial Intelligence
- Machine learning
- Operational analytics
- Trading optimization
- Remote sensing
- Blockchain
- Edge devices
- Drones
- Smart agriculture

- End-use energy productivity
 - Electrification
 - Efficiency
 - System optimization
- Clean electricity
 - Wind/solar
 - Nuclear (SMRs)
 - Battery storage
- Zero carbon fuels
 - Biofuels
 - H₂ fuels
 - Syn fuels
- CO₂ capture & storage
 - CCUS/caverns
 - CO₂ trunk pipeline
 - Injection wells
- Reduce non-CO₂ emissions
 - Methane emissions
 - FluoroCarbon emissions
 - Sensors/scans
- Enhanced land sinks
 - Forrest management
 - Smart agriculture
 - Measurement/verification

These five key shifts combine to reframe our mindset and approach to successfully develop and build the infrastructure of net zero, within thirty years.