
WHERE TO PLAY:
GAME-CHANGING TECHNOLOGIES FOR ENERGY
ITONICS

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Introduction

The energy sector is in the midst of a massive transition. The pressure to transform is mounting, propelled forward by the environmental crisis and looming net-zero deadlines for governments and corporates worldwide.

Moreover, the last two years have been characterized by disruption on a global scale. The pandemic's lockdowns temporarily subdued energy consumption and demand, resulting in cascading effects in supply and price as demand quickly rebounded towards the end of 2020 and left many producers scrambling. Now—having surpassed or soon expected to surpass pre-pandemic levels—demand shows little sign of waning as developing and emerging nations seek to grow their economies and raise the quality of life for their citizens.

So the resounding question remains: how will we meet rising energy demands alongside the sustainability imperative?

The ways in which organizations and governments decide to answer this question will have a profound impact on many other industries, as well as on lives, livelihoods, and future generations. With the **Decade of Action** in full effect, there is little doubt that the solution sits at the intersection of ESG (environmental, social, and governance) regulation, resilience in the face of volatile market behavior, and disruptive technological innovation. These, in short, are the forces shaping the future of the energy industry.

Organizations that understand and build the capacity to navigate these forces will be well-positioned to meet rising energy demands and comply with the transition to renewable energy. And those that go beyond compliance and pioneer this transition through foresight and innovation will establish themselves as leaders in the industry.

We aim to showcase the exciting possibilities and key solution drivers set to usher in this transition period in the energy sector. The information contained within this report is interlinked with the ITONICS Innovation Platform to help organizations better connect the dots between these drivers of change, anticipate the most rewarding opportunities for the future, and gain strategic advantage. We hope that our selection of game-changing technologies and industry-relevant applications help catalyze new thinking so that organizations can position themselves as protagonists in the effort to mitigate climate change and optimize their business models.

An Introduction to Technology Scouting

End2end innovation management begins by asking the fundamental question, **Where to Play**. Answering this question relies on several congruent activities and internal capabilities that primarily fall within the discipline of Foresight and Strategy, as advocated by our distinct **ITONICS COFIM** model. Organizations equipped with strong foresight capabilities can align their strategy with future scenarios and build resilience in an increasingly uncertain and competitive landscape.

Essential in **Foresight and Strategy** is an organization's capacity to scan its business environment comprehensively and continuously—environmental scanning. This is the capability to scan the horizon for weak signals that might indicate larger shifts and influence or disrupt the environment. It begins with the collection of vast amounts of data from which patterns are revealed through sensemaking analysis.

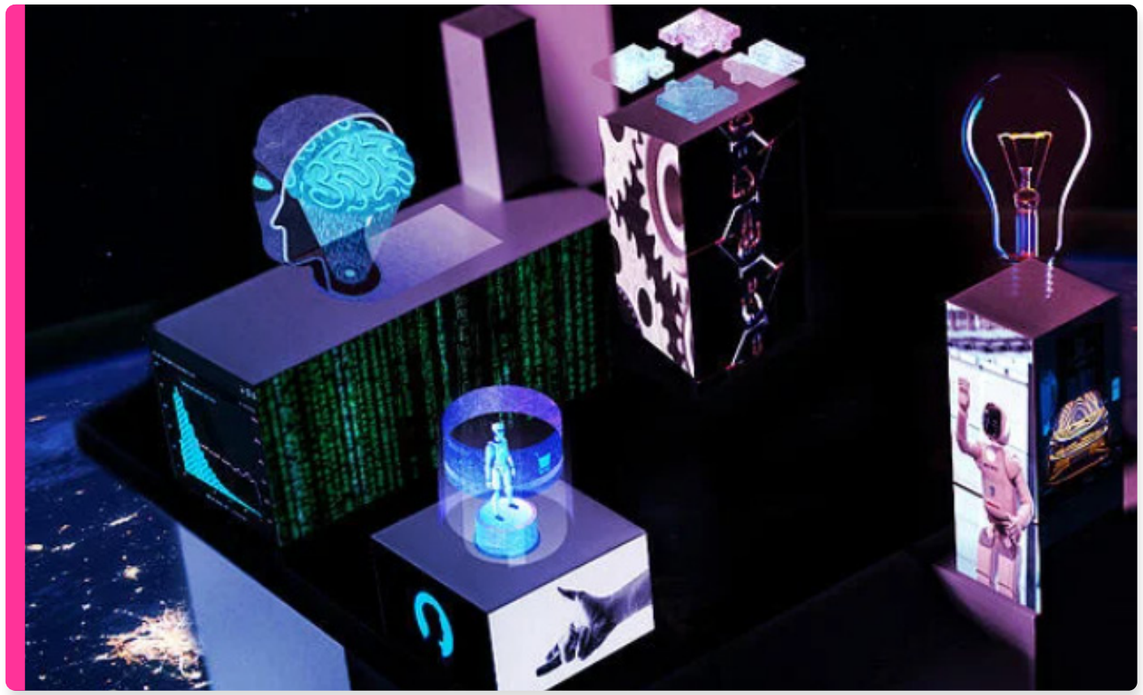
Environmental scanning focuses on control objectives that enhance innovation intelligence, thereby enabling the identification of new opportunities for growth, informing strategic priorities, and shaping future goals. These include capability supervision, competitor watch, trend scouting, and technology scouting.

As the focus of this industry report, **technology scouting** is the process of observing technological shifts and developments by collecting pertinent data, contextualizing change to uncover discernable patterns as weak signals, and identifying emerging technologies that hold both impact and relevance.

Actively screening for shifts in technology adoption, R&D, and patents serves as an early-warning system to help organizations anticipate and respond to changes while also minimizing risk.

Applying an industry lens to the process of technology scouting helps organizations direct their focus and resources more optimally.

And by gaining an understanding of the technological developments and adoption trends that may present future opportunities in their industry, they can equip themselves with the innovation intelligence needed to take decisive, strategic action and ultimately gain a competitive advantage.



The Role of Technologies in Innovation

Emerging, evolving, and disruptive technologies serve as solution drivers, helping innovators connect the dots between their current and future states. These are the tools capable of meeting—and sometimes, creating—new needs, desires, and demands.

Technologies enable new business models, products, and services. They have the potential to meaningfully expand an organization's existing portfolio and transform an entire industry.

The Interplay between Technologies and Trends

Technologies and trends are complementary elements that interact with and influence one another. Trends are expressions of new consumer attitudes, expectations, or behaviors—an indication of market pull; whereas technologies are designed either in response to these shifts or as precursors to nascent demands—representing a market push.

Together this push and pull exert force on the market, driving change forward. It is organizations' ability to pre-empt or respond to this change through innovation that determines their success.

Determining Industry Relevance

Environmental scanning is a divergent exercise; too narrow an approach and important opportunities can easily be missed. And while all elements in the ITONICS portfolio hold relevance—the degree of relevance differs depending on the industry in which your organization operates.

To help provide this industry lens, ITONICS analysts have performed relevance analysis to identify the Technologies and other elements that are most relevant and likely to be game changers in each respective industry.

Our team of analysts monitored the frequency with which each Technology appeared in a given industry. Instances of real-world applications, R&D, patents, and startup activities were tagged with relevant industries through a process combining manual and automated data classification.

This initial mapping of the ITONICS portfolio served as hypotheses of industry relevance. These hypotheses were further validated and enriched through additional quantitative and qualitative industry research to arrive at nine industry packages.

Each industry package, available on the ITONICS Innovation Platform, displays the Technologies, Trends, and Inspirations that represent the most relevant—that is, impactful, disruptive, and transformative—areas in which to play.

Technology Scouting with ITONICS

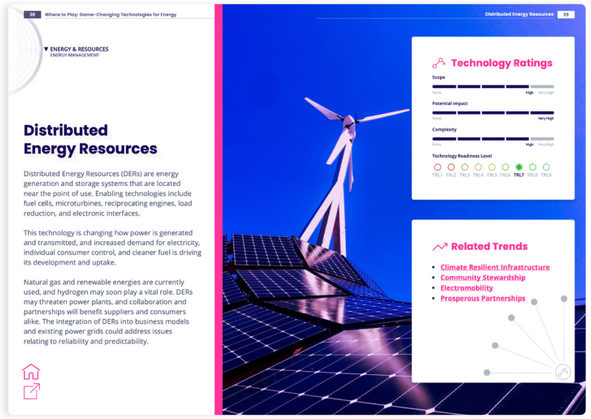
This report provides a starting point from which to embark on your organization's technology scouting. It presents 26 game-changing Technologies for energy. Through a process of relevance analysis, these have been identified as most relevant and impactful to innovation in the industry.

Each can all be explored on the ITONICS **Teaser Technology Radar**, filtered for energy. Additionally, our pick of the industry's top five game-changing Technologies is unpacked in further detail in this report.

How to Read the Technologies

The **Synopsis** gives a brief overview of the Technology, explaining why it is important, what is required to enable it, how it has evolved, and any current limitations and opportunities.

The **Segmentation** of the Technology is indicated corresponding to the relevant categories that appear on the ITONICS Radar: Chemicals & Materials, Energy & Resources, Engineering, Healthcare & Life Sciences, ICT, and Mobility. Listed below, the **Sub-segmentation** provides a more narrow scope as to the area of technological development.



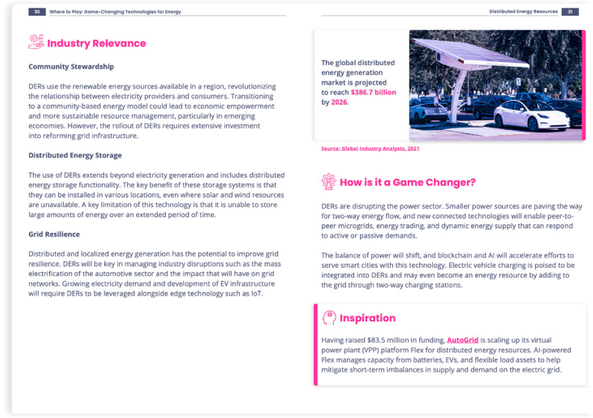
In the navigation bar, the ⌂ icon will bring you back to the Table of Contents page. The ⧉ button will open up the individual element in the ITONICS **Teaser Technology Radar**. Here you can deep dive into the Implications for Innovation associated with the Technology and view the interconnected elements that influence and impact it, including related Trends, Inspirations, and other Technologies.

The **Technology Ratings** look at the parameters of Scope, Potential Impact, Complexity, and Technology Readiness Level (TRL).

Related Trends show the elements that are influenced by and have an influence on the Technology, its development, and adoption. This network provides greater context as to the interplay between elements and points to possible opportunities.

Industry Relevance unpacks the industry-specific applications and potential use-cases that are most prominent with regard to the Technology. Each point looks at the strategic advantage gained through adoption of the Technology and the considerations for its future development.

How is this a Game Changer? elaborates on how the Technology may contribute to or influence possible future scenarios. The relationship between the Technology and nascent demands is explored through a future-oriented lens.

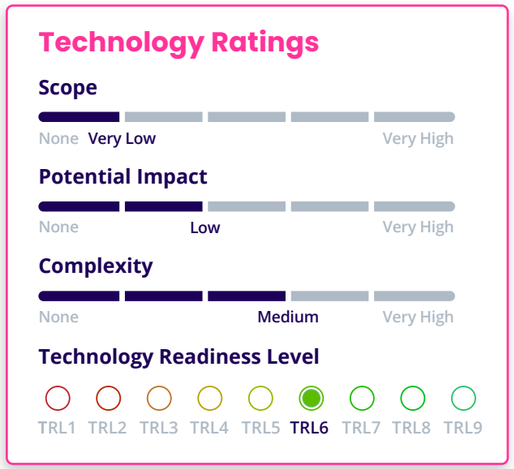


Inspirations provide evidence of how organizations are applying the Technology in the real world. They serve as springboards for ideation, helping innovators look beyond their category, connect information in new ways, and nurture fresh thinking.

ITONICS Ratings

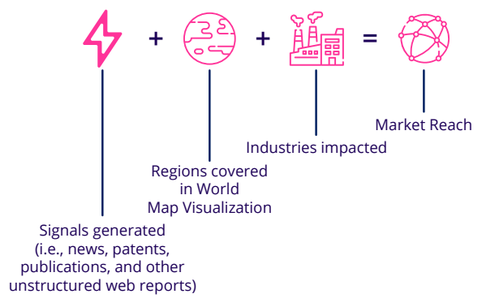
The evaluation of trends or technologies is one of the most important activities in innovation management. The goal is to predict future changes in your industry and whether they are relevant to your organization.

ITONICS Trends and Technologies are presented with ratings that help foresight teams focus their attention and identify relevance based on their unique set of strategic objectives.



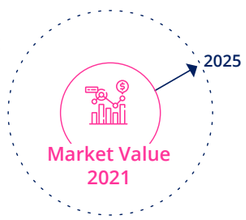
Scope: *How far-reaching is the potential influence of this element on this market?*

ITONICS Insights tool uses keywords to retrieve data across three dimensions and derive an aggregated mean value to indicate the market reach of each Technology.



Potential Impact: *How high is the potential impact of this element on the market?*

Market growth data for each Technology is collected from a minimum of 5 verifiable sources, aggregated and extrapolated to 2025.



Scale: Projected market value in 2025 (USD billion):

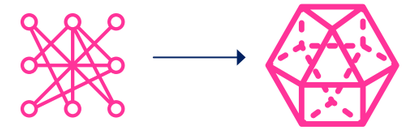
- Very Low: >10 bil.
- Low: 10-50 bil.
- Medium: 50-500 bil.
- High: 500-1,000 bil.
- Very High: >1,000 bil.

Our team of analysts uses advanced query and **ITONICS Insights** to garner the relevant information alongside our research and statistically derive the ratings from quantifiable historical and present data.

Each Technology is rated on Scope, Potential Impact, Complexity, and Technology Readiness Level (TRL) to provide targeted and tailored analysis at your fingertips.

Complexity: *How high is the complexity of this element?*

A complexity score is derived based on the number of connections each Technology forms with other elements.



Technology Readiness Level (TRL): *How mature is this element in the market?*

Each Technology is mapped by its Technology Readiness Level (TRL) to determine its relative maturity.

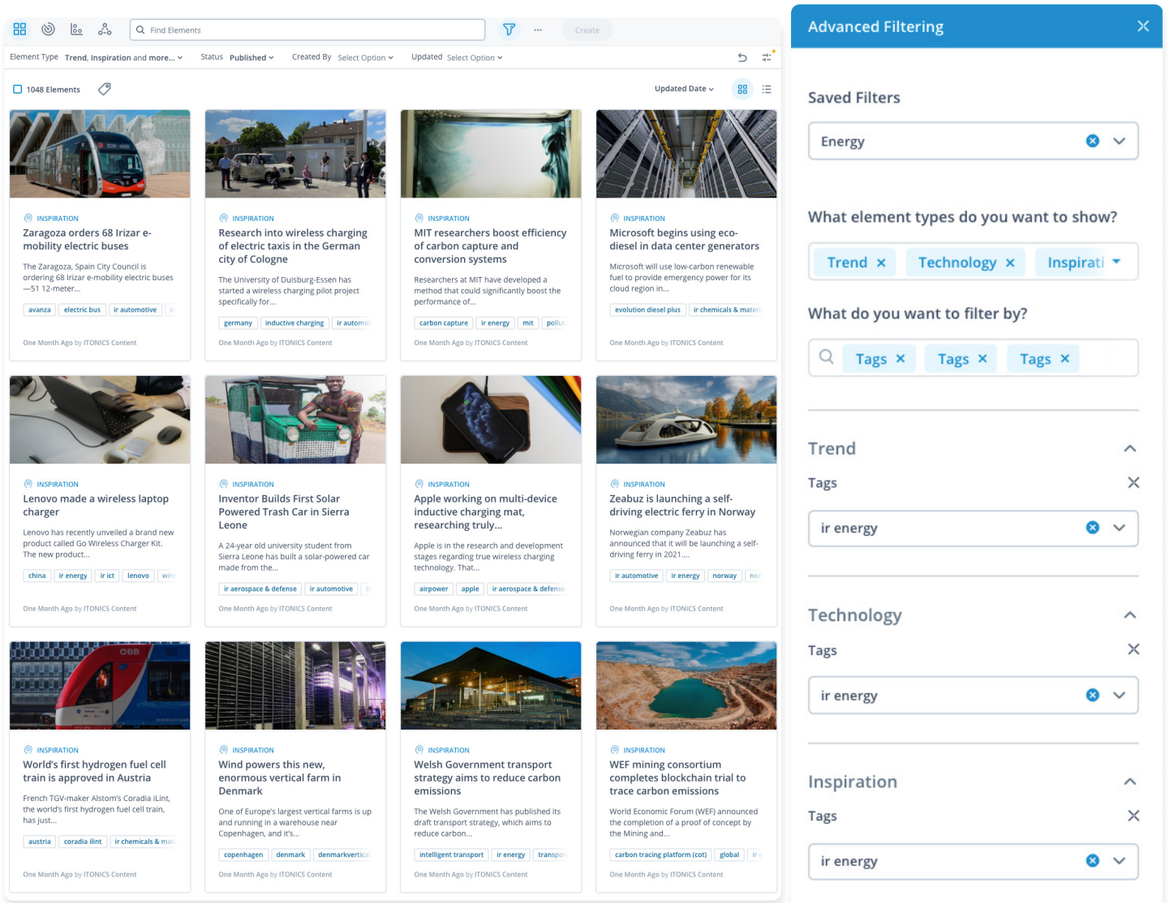
PHASE	TRL	DEFINITION
RESEARCH	1	Basic principles observed
	2	Concept formulated
	3	Experimental proof of concept
DEVELOPMENT	4	Validated in lab
	5	Validated in relevant environment
	6	Demonstrated in relevant environment
DEPLOYMENT	7	System prototype demonstrated in operational environment
	8	System complete and qualified
	9	Actual system proven in operational environment

Exploring the ITONICS Radar

Having the right tools to manage innovations, technologies, projects, and opportunities is vital to act on your organization's innovation strategy in an increasingly uncertain and dynamic world. After all, what you can't manage, you cannot change.

Get started by exploring the ITONICS **Teaser Technology Radar** and **Teaser Trend Radar** displaying the elements that are most relevant to your industry. Here you will find a read-only overview of each Technology and Trend.

Beyond what's available in the Teaser, the full content on the ITONICS Innovation Platform provides deeper insight into each Technology. It allows users to interact with and configure different elements to derive greater meaning and prompt informed decision-making.



The ITONICS Innovation Platform provides access to:

- The full portfolio of **175+ Trends and Technologies**, each with detailed explanations of how they have developed, where they are currently having an impact, and how they could evolve into the future.
- **7,000+ Inspirations**, continually updated to illustrate how Trends and Technologies are being activated and brought to life by innovators, businesses, and consumers.
- The ability to set **Internal Ratings** such as Business Relevance, Strategic Fit, Internal Know-How, and Need for Action. Undertaken as a collaborative evaluation exercise within your organization, these ratings help build the consensus and commitment needed in the innovation journey.
- Interactive **Network Graph** visualizations that display first- and second-level relations for a selected element. New relations that hold strategic relevance to your organization can also be added to any network graph.
- Various **Tags** attributed to each element to help users focus their searches. A **Tag Filter** function allows advanced searching by tags and gives suggestions for related tags. To view the Trends, Technologies, and Inspirations that are most relevant to energy, use **Advanced Filtering** and select the **Saved Filter**: **Energy.**

For full access to this content and functionality, register an account on ITONICS Cloud for free today.

REGISTER

Forces Shaping the Future of Energy

Context of Change

Defining the objectives and scope of environmental scanning activities like technology scouting requires a clear understanding of the context of change in your industry. Context provides a foundation for identifying and assessing the driving forces shaping the future. It points to evidence of where we see change happening in social, technological, economic, environmental, and political spheres and where the change will expand to next. It is the landscape upon which trends and technologies play out; the ability to navigate this landscape is the ability to adequately prepare for possible futures.

Forces Shaping the Future

Around the globe, several driving forces are impacting the energy industry. There are increased coalitions between public and private sector stakeholders as coordinated efforts are required to eliminate fossil fuels from value chains. The post-pandemic landscape presents a particular challenge for how clean energy will be prioritized amidst global economic instability.

Multinational gas and oil companies are leveraging emerging technologies to find quick wins alongside refocused M&A strategies to move towards renewables. Infrastructural redevelopment is also becoming a non-negotiable consideration in this period of intense flux for the energy sector.

Here we'll discuss some of the forces shaping the future of the energy industry.

I STRATEGIC TRANSITIONS TO DECARBONIZATION

will determine emissions trajectories for years to come.

An urgent imperative in the energy sector is devising strategies for transitioning to decarbonization without sacrificing financial targets. Technologies like **Carbon Capture and Storage** are seen as temporary solutions to help reduce greenhouse gas emissions and convert carbon for other uses in the interim as full decarbonization strategies take root. Technological advancement is needed to make renewable energy cost-effective and scalable. Moreover, a smooth and successful transition relies on buy-in from those most affected, decisive governmental policy, and intersectoral and international cooperation.

II GLOBAL ENERGY DEMAND

will continue to rise, influencing growth and geopolitics.

Following the previous year's dip in electricity consumption, global energy demand rose by 4.6% in 2021—a year-on-year increase that surpassed pre-pandemic growth rates. As developing and emerging nations experience economic growth, demand for affordable energy is expected to increase further. These nations have an opportunity to leapfrog to more sustainable ESG solutions to meet their infrastructural and societal needs. Meanwhile, China is positioning itself to play an increasingly prominent role in meeting energy demands in the global south, influencing geopolitics and the transition to renewables.

III THE RENEWABLE ENERGY RACE

will be a battleground for the next global superpower.

Expect jockeying from global superpowers as to which nation will be the go-to provider of renewable energy, especially for the growing demand from developing and emerging economies. Current data indicates that China could win this race as they are currently responsible for nearly 50% of the available renewable energy. While India, the US, and key EU member states attempt to catch up, success in the renewable energy race will depend on the ability to harness adjacent technologies such as **Hydrogen Storage** and **Distributed Energy Resources**.

IV CONSUMER-LED SHIFTS

will help expedite the energy transition.

Energy consumers—encompassing all sectors, organizations, and individuals who use energy or energy feedstocks—have a pivotal role to play in smoothing the energy transition. Increased demand for decarbonization will help commercialize low-carbon technology and renewable energy. Energy companies and policymakers must address the barriers to clean energy adoption, including availability, cost, and reliability. Additionally, while it is certain that global energy demand will increase, more sustainable consumption behavior can be influenced by increasing environmental awareness, emphasizing financial benefits, and offering compelling incentives.

V PROACTIVE RENEWABLE ENERGY INVESTMENTS

will determine future success for incumbents.

Oil and gas companies that have long relied upon and profited from the status quo will need to develop new strategies to integrate renewable energy into their business models. This also requires a transition period to change systems and acquire the enabling capabilities, including technology and talent. Incumbents must take proactive measures rather than passively await forthcoming ESG regulations. Their future success will rely on strategic investments and M&A opportunities as well as their ability to help generate the demand for renewables within the next decade.

VI CIRCULAR OPERATIONAL MODELS

will be the next normal in the energy sector.

Circular practices will be critical to organizations aiming to transition from fossil fuels to renewable energy. Expect governmental and ESG regulatory pushes for organizations to examine their supply chain and give a second life to fossil fuel-based infrastructure. Industry behavior suggests that circularity in the energy sector could kickstart innovation and develop new business models in the next decade. This could range from repurposing oil fields as carbon storage units, converting pipelines, and recycling electric vehicle (EV) batteries to meet the growing cobalt demand.

» ***Use this context to help better understand the strategic importance and innovation opportunities associated with the game-changing technologies identified for the energy industry.***

Game-Changing Technologies for Energy

Technology Navigation

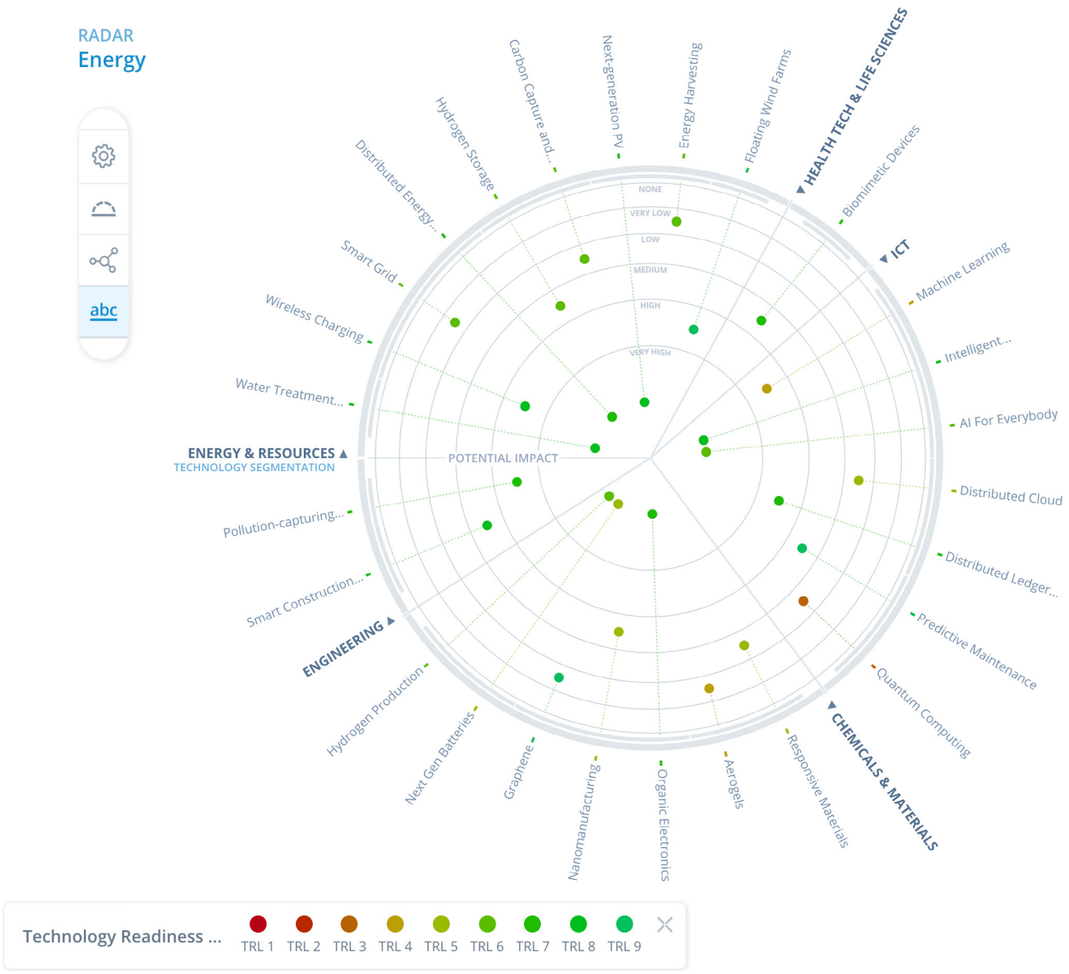
Through a process of qualitative and quantitative industry research, our team of analysts conducted relevance analysis in order to identify the Technologies within our portfolio that are **most relevant and influential in the energy industry.**

Game-Changing Technologies for Energy

Explore the selection of Technologies at play in the energy industry. **Click on the Technology below** to view it in the ITONICS Teaser Technology Radar:

- Aerogels
- AI for Everybody
- Biomimetic Devices
- Carbon Capture and Storage*
- Distributed Cloud
- Distributed Energy Resources*
- Distributed Ledger Technology
- Energy Harvesting
- Floating Wind Farms*
- Graphene
- Hydrogen Production*
- Hydrogen Storage
- Intelligent Manufacturing
- Machine Learning
- Nanomanufacturing
- Next Gen Batteries
- Next Gen PV*
- Organic Electronics
- Pollution-capturing Devices
- Predictive Maintenance
- Quantum Computing
- Responsive Materials
- Smart Construction Sites
- Smart Grid
- Water Treatment Technologies
- Wireless Charging

*These Technologies make up ITONICS' pick of the energy industry's top 5 game-changing Technologies. These are unpacked in further detail in this report.



ITONICS Top 5 Game-Changing Technologies for Energy

Click below to read more about the industry potential of these Technologies and examples of how organizations are applying them as solutions:

1. Carbon Capture and Storage
2. Distributed Energy Resources
3. Floating Wind Farms
4. Hydrogen Production
5. Next Gen PV

▼ ENERGY & RESOURCES
STORAGE

Carbon Capture and Storage

Carbon Capture and Storage (CCS) refers to the practice of capturing CO_2 emissions from different sources and storing or reusing these emissions in order to keep them from entering the atmosphere. CO_2 capture and storage is a technology with the potential to significantly reduce CO_2 emissions within 10 to 20 years.

However, this currently energy- and water-intensive technology could place stress on water resources for approximately 43% of the world's power plants, exacerbating issues of water scarcity. Additionally, the high costs associated with this technology could hinder its widespread adoption.

Technology Ratings

Scope

None — **High** — Very High

Potential Impact

None — **Low** — Very High

Complexity

None — **Medium** — Very High

Technology Readiness Level

TRL1 TRL2 TRL3 TRL4 TRL5 **TRL6** TRL7 TRL8 TRL9

Related Trends

- Alternative Energy Transition
- Beyond Compliance
- Carbon as a Currency
- Circular Economy
- ESG Investing

Industry Relevance

Net-Zero Transition

CCS technology is one method companies can use to transition to carbon neutrality. Implementing this technology, alongside other renewable energy initiatives and nature-based solutions, can help achieve net-zero commitments in compliance with the Paris Climate Agreement. CCS can help bridge the gap until next-generation zero- or negative-carbon energy technologies emerge.

Blue Hydrogen Production

CCS could be the key to unlocking hydrogen's potential as a near-zero-emission energy source. Capturing CO_2 during hydrogen production results in blue hydrogen. While its true sustainability is debated, blue hydrogen is less carbon-intensive than grey hydrogen (a by-product of an industrial process) and more cost-effective than green hydrogen (produced entirely from renewable sources).

Alternative Fuel Production

Utilizing, rather than simply storing, captured CO_2 increases the economic viability of the technology. Captured CO_2 can be used as a feedstock to produce alternative synthetic fuels. It can also be converted into commercial products such as plastics, concrete, and reactants for chemical synthesis. Producing high-value fuels and chemicals from captured CO_2 may serve as an important means of offsetting the cost of capture operations.

"Deliberate carbon dioxide removal (CDR) from the atmosphere has the potential to compensate for residual CO_2 emissions to reach net-zero CO_2 emissions or to generate net negative CO_2 emissions."

Source: IPCC Sixth Assessment Report, 2021

How is it a Game Changer?

Retrofitting carbon capture and storage technology in existing energy and power plants can drastically reduce CO_2 emissions resulting from energy generation, which otherwise would amount to 600 billion tonnes of CO_2 in the next 50 years, according to the International Energy Agency. High-emissions sectors like cement plants, iron, steel, and chemical manufacturing factories can benefit greatly from carbon capturing and storage as a means of reducing emissions and transitioning into more sustainable industries.

Inspiration

US-based startup **Noya** retrofits cooling towers on buildings to pull CO_2 from the atmosphere. It makes use of the existing infrastructure, combined with a non-toxic CO_2-absorbing chemical blend and installation of downstream CO_2 processing equipment. Noya then sells the captured CO_2, sharing the profits with the cooling tower owners to help offset operational costs.

▼ ENERGY & RESOURCES
ENERGY MANAGEMENT

Distributed Energy Resources

Distributed Energy Resources (DERs) are energy generation and storage systems that are located near the point of use. Enabling technologies include fuel cells, microturbines, reciprocating engines, load reduction, and electronic interfaces.

This technology is changing how power is generated and transmitted, and increased demand for electricity, individual consumer control, and cleaner fuel is driving its development and uptake.

Natural gas and renewable energies are currently used, and hydrogen may soon play a vital role. DERs may threaten power plants, and collaboration and partnerships will benefit suppliers and consumers alike. The integration of DERs into business models and existing power grids could address issues relating to reliability and predictability.

Technology Ratings

Scope

None — High — Very High

Potential Impact

None — Very High

Complexity

None — High — Very High

Technology Readiness Level

TRL1 TRL2 TRL3 TRL4 TRL5 TRL6 **TRL7** TRL8 TRL9

Related Trends

- Climate Resilient Infrastructure
- Community Stewardship
- Electromobility
- Prosperous Partnerships

Industry Relevance

Community Stewardship

DERs use the renewable energy sources available in a region, revolutionizing the relationship between electricity providers and consumers. Transitioning to a community-based energy model could lead to economic empowerment and more sustainable resource management, particularly in emerging economies. However, the rollout of DERs requires extensive investment into reforming grid infrastructure.

Distributed Energy Storage

The use of DERs extends beyond electricity generation and includes distributed energy storage functionality. The key benefit of these storage systems is that they can be installed in various locations, even where solar and wind resources are unavailable. A key limitation of this technology is that it is unable to store large amounts of energy over an extended period of time.

Grid Resilience

Distributed and localized energy generation has the potential to improve grid resilience. DERs will be key in managing industry disruptions such as the mass electrification of the automotive sector and the impact that will have on grid networks. Growing electricity demand and development of EV infrastructure will require DERs to be leveraged alongside edge technology such as IoT.

The global distributed energy generation market is projected to reach **$386.7 billion** by **2026**.

Source: Global Industry Analysts, 2021

How is it a Game Changer?

DERs are disrupting the power sector. Smaller power sources are paving the way for two-way energy flow, and new connected technologies will enable peer-to-peer microgrids, energy trading, and dynamic energy supply that can respond to active or passive demands.

The balance of power will shift, and blockchain and AI will accelerate efforts to serve smart cities with this technology. Electric vehicle charging is poised to be integrated into DERs and may even become an energy resource by adding to the grid through two-way charging stations.

Inspiration

Having raised $83.5 million in funding, **AutoGrid** is scaling up its virtual power plant (VPP) platform Flex for distributed energy resources. AI-powered Flex manages capacity from batteries, EVs, and flexible load assets to help mitigate short-term imbalances in supply and demand on the electric grid.

▼ ENERGY & RESOURCES
GREEN ENERGY TECHNOLOGY

Floating Wind Farms

Floating Wind Farms are wind energy generation facilities designed to function further away from the seashore by utilizing floating offshore platforms to create infrastructure deeper in the ocean.

This technology uses the iceberg principle and is placed a minimum of 60 meters deep into the water to prevent drifting. Floating Wind Farms harness the power of the strong winds out at sea, surpassing the capacity factor of thermal generation.

This technology stands to revolutionize the clean energy production industry. Limitations include high installation costs and difficulty gaining public buy-in. Additionally, this technology is limited to top wind speeds, making it unsuitable for hurricane-prone areas.

Technology Ratings

Scope

None — **Medium** — Very High

Potential Impact

None — **High** — Very High

Complexity

None — **Low** — Very High

Technology Readiness Level

TRL1 TRL2 TRL3 TRL4 TRL5 TRL6 TRL7 TRL8 **TRL9**

Related Trends

- Alternative Energy Transition
- Carbon as a Currency
- ESG Investing

Industry Relevance

Transitioning Offshore Oil and Gas

Floating wind turbines can provide electricity to offshore oil and gas infrastructure, reducing their operational greenhouse gas emissions. As the fossil fuel industry is increased pressure to meet net-zero targets, moving towards clean energy generation from wind turbines is a sustainable solution for oil and gas companies navigating the energy transition.

Supporting Green Recovery

Offshore wind leasing programs allow investors to bid on areas of seabed for wind farm developments. Beyond promoting the use of renewable energy and creating demand for skilled green jobs, these programs can generate new income streams for nations and help revitalize local areas, including harbors, ports and shipyards.

Mobile Offshore Wind Units

Mobile offshore wind units (MOWUs) are floating wind turbines that can be moved to different locations as optimal climate conditions change or to avoid harsh environmental conditions that conventional turbines may not withstand. This infrastructure is ideal for powering offshore networks that have electricity needs for a fixed period of time.

Source: Cornell Chronicle, 2021

How is it a Game Changer?

Floating Wind Farms will see collaborations and investments in the future, resulting in cost reduction over time. Technologies like autonomous robots and AI will play a crucial role in the installation and design process, and machine learning will help identify and predict the risk of operation failure, saving costs and reducing the risk for human personnel.

Although traditional wind farms will continue to grow, Floating Wind Farms will take wind energy generation to the next level.

Inspiration

South Korea's Hyundai **Heavy Industries** has unveiled designs for a prototype floating offshore wind turbine installation. The Korean Offshore Wind Power Floating Model is for a 10 MW-class floating offshore wind turbine using a semi-submersible similar to that used for oil production systems.

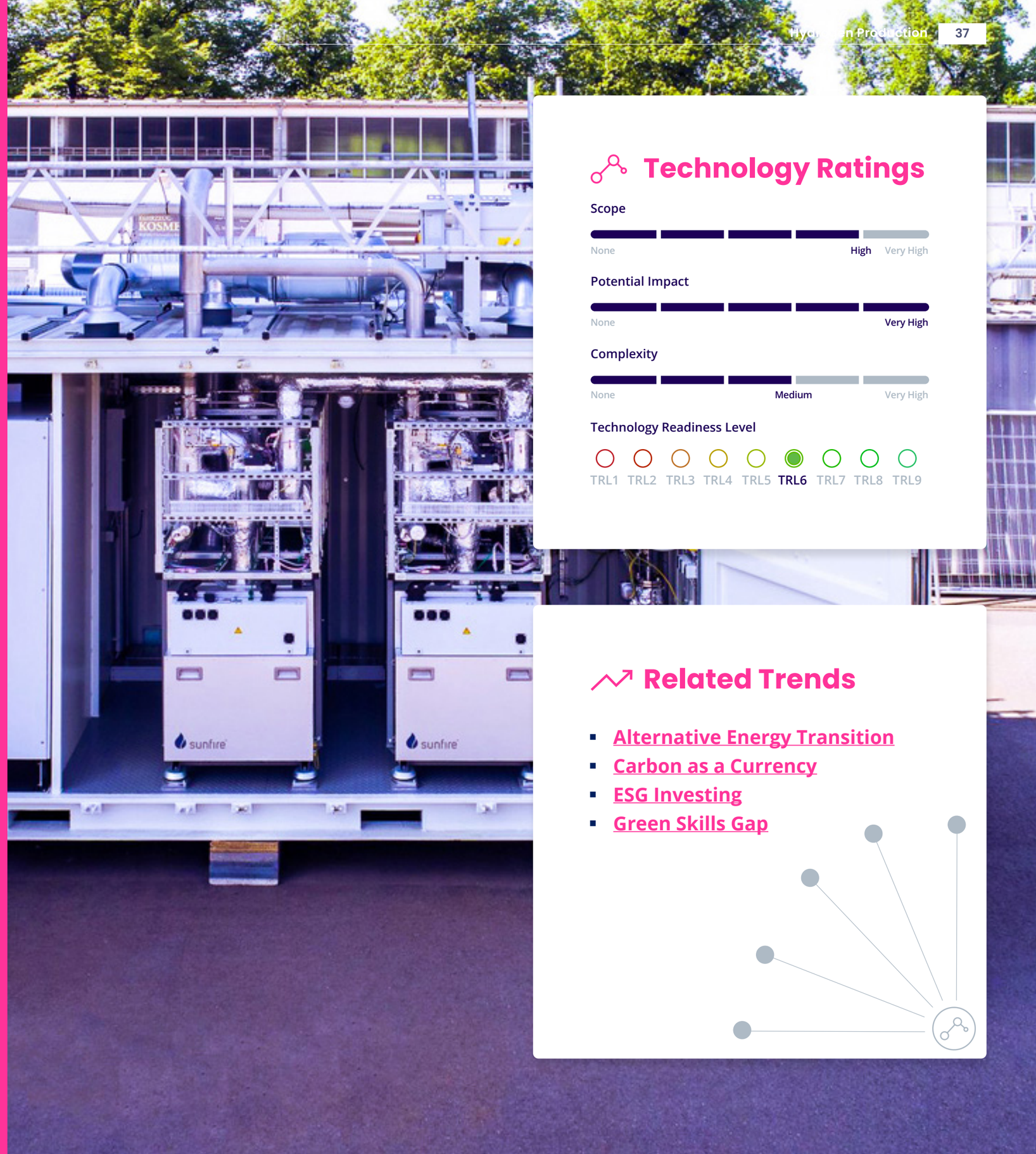
▼ CHEMICALS & MATERIALS
FUEL CELLS & BATTERY

Hydrogen Production

Hydrogen production refers to the industrial processes involved in generating hydrogen gas. Presently, most hydrogen is produced from fossil fuels by the steam reforming of natural gas, partial oxidation of methane, and coal gasification.

Other methods include biomass gasification, methane pyrolysis, and electrolysis of water. The main challenge in hydrogen production remains the high cost of production. Most of the hydrogen produced in the world today is from fossil fuels, which causes carbon emissions.

To establish a hydrogen economy, it is vital to develop affordable methods of mass-producing hydrogen and implement measures like using renewable energy and carbon capture systems to produce hydrogen sustainably.



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Related Trends

- Alternative Energy Transition
- Carbon as a Currency
- ESG Investing
- Green Skills Gap

Industry Relevance

Power and Heat Generation

Hydrogen can be mixed with natural gas to generate low-carbon electricity and heat. Several projects worldwide are demonstrating mixtures with hydrogen concentrations as high as 20%. However, the long-term effects of hydrogen on materials and equipment are still unclear, making it difficult for industries to scale hydrogen mixing.

Methanol and Dimethyl Production

Hydrogen can be used to produce methanol and dimethyl (DME) fuel, which is an alternative to diesel. Due to its lack of carbon-to-carbon bonds, using DME as an alternative to diesel can virtually eliminate particulate emissions and remove the need for costly diesel particulate filters.

Hydrogen Fuel Cell EVs

Fuel cell electric vehicles (FCEVs) are powered by hydrogen and represent a zero-emission solution for the automotive industry. Compared to the lithium-ion batteries utilized in most electric vehicles, fuel cells promise longer range, faster refueling, and lighter-weight vehicles. However, FCEVs require expensive infrastructure.

The global hydrogen market is projected to be worth **$201 billion** by **2025**, up from $130 billion in 2020.

Source: Markets and Markets, 2021

How is it a Game Changer?

With advances in electrolyzer and renewable electricity generation technologies, the future of hydrogen production will move away from fossil fuels to sustainable methods. Hydrogen being the most abundant chemical in the universe means its use has the potential to contribute significantly to the fight against global warming and climate change if produced sustainably. We are gradually moving towards a hydrogen economy where green hydrogen will decarbonize many industries in which reducing emissions is difficult, including chemical production, long-haul transport, iron, and steel.

Inspiration

Finland's first **green hydrogen production plant** will be constructed in Harjavalta, beginning in 2022. With a capacity of 20MW, the plant is expected to provide green electricity for industrial applications and support industries with oxygen and thermal energy produced as a by-product.

▼ ENERGY & RESOURCES
RENEWABLE ENERGY & POWER SOURCES

Next Gen PV

Scientists have long sought a viable substitute for the current silicon-based solar cells. Next-generation photovoltaic cells (PVs) made of perovskite offer the potential for low-cost, low-temperature manufacturing of lightweight, ultrathin, flexible cells.

These properties make them useful for applications in fields ranging from automotive to consumer electronics to construction.

"Tuning" perovskite enables different layers to absorb different wavelengths of light—and thus, more light—than standard PVs. Layering perovskite over existing silicon panels enables them to absorb additional wavelengths, boosting their efficiency by 30%. While lab tests prove promising, this technology's viability in terms of scalability and durability has not yet been tested.

Technology Ratings

Scope

None — **Medium** — Very High

Potential Impact

None — **Very High**

Complexity

None — **High** — Very High

Technology Readiness Level

TRL1 TRL2 TRL3 TRL4 TRL5 TRL6 TRL7 **TRL8** TRL9

Related Trends

- Alternative Energy Transition
- Carbon as a Currency
- ESG Investing
- Green Skills Gap

Industry Relevance

Increased Solar Panel Efficiency

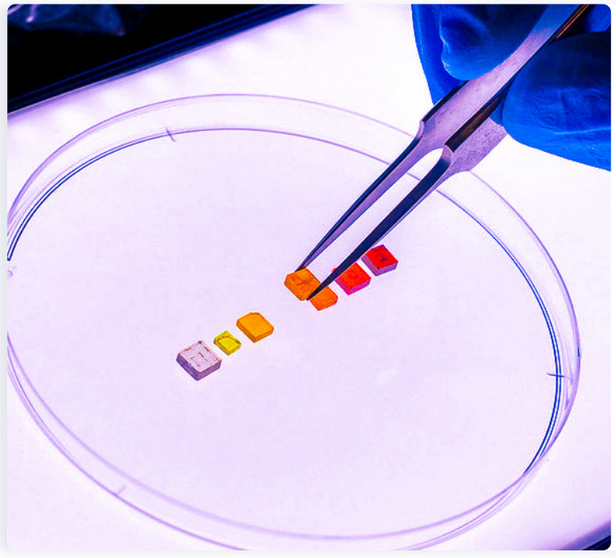
A unique selling point of perovskite solar cells is that they are able to react and process different wavelengths of light, which means greater capacity to convert more of the available light into electricity. This feature will drastically enhance solar panel efficiency, especially if perovskite solar cells have similar life spans to silicon solar panels (approximately 20 years).

Optimal Energy Payback Time

Solar panels made with two perovskite layers require less energy input to produce, and each layer can be optimized to absorb a section of the electromagnetic spectrum. This means that a perovskite-perovskite tandem cell has a better energy payback time ratio than a silicon panel, in addition to lower emissions over its lifetime.

Building-Related Needs

Perovskite PV cells can be used in designing sophisticated housing materials such as high-transmittance windows capable of balancing indoor temperatures and lighting. As more flexible forms emerge, this perovskite-based smart material technology will also become an option for retrofitting a wide range of pre-existing building infrastructure and even irregularly shaped surfaces.



The energy conversion efficiency of perovskite solar cells has gone from **3%** in **2006**, when more extensive R&D began, to over **25%** in **2020**.

Source: US Department of Energy

How is it a Game Changer?

Perovskites are likely to be a significant development in the near future in the field of renewable energy generation. The characteristics of this material make it a very cheap, high-performance material for PV cells which could drive a major shift from fossil fuels to solar cells in the near future.

The next generation of photovoltaics based on perovskites will hopefully also reduce the price of solar cells, transform energy harvesting, and help to mitigate climate change.

Inspiration

Australia's national science agency, **CSIRO**, is partnering with Space Machines Company (SMC) to test its next-generation solar PV cell technology. CSIRO will examine the potential of its perovskite-based solar cells on SMC's spacecraft Optimus-1.

Conclusion

Closing Remarks

The seismic industrial shifts occurring in energy will require organizations to be agile and develop resilient innovation strategies. The forces shaping the future in this sector revolve around increasing regulatory pressure, post-pandemic demand surges, as well as the race to be a renewable energy superpower.

Businesses will need to think strategically about meeting rising global energy demand, especially from developing and emerging nations, while not neglecting their move towards eliminating fossil fuels.

Technologies such as **Carbon Capture Storage** and **Pollution Capturing Devices** are crucial to the energy transition, reducing greenhouse gasses and converting carbon for other uses in the interim. However, organizations must be aware that carbon recycling technology is not a final solution and that decarbonization is the north star metric.

With technologies such as **Distributed Energy Resources** optimizing consumption processes and directly affecting power plants, the need for **Intelligent Manufacturing** and the repurposing of fossil fuel-based infrastructure will be non-negotiable. Businesses need to harness solution drivers to embed circularity within their value chains.

Two critical factors that organizations will need to keep a keen eye on are legislation and consumer sentiments. Conscious consumerism is driving demand in solar energy for residential areas and helping to commercialize clean energy technology. Meanwhile, institutions such as the UN, IRENA, and government coalitions will continue to place pressure on organizations to transition from fossil fuels to renewables. Off the back of the COP 26 UN Climate Change Conference in November 2021, this pressure will only escalate.

Within this context of change, we provide a set of questions for organizations in energy to consider in the hope of nurturing fresh thinking about the future they wish to be a part of, and play an active role in helping to create.

- What if the long-term resonance of the pandemic delays the global decarbonization process?
- What if key players in the energy sector meet rising global energy demands while aligning with UN SDG targets?
- What if more stringent ESG regulations render some energy incumbents obsolete, making space for disruptive new players?
- What if energy companies provide diversified value that meets both ESG imperatives as well as shifting consumer desires?
- What if oil and gas corporate giants begin spearheading a mass transition to renewable energy?
- What if a critical mass of disruptive start-ups emerge to deliver the key solution drivers needed to optimize energy sector circularity?

There are countless questions to be asked about what the future holds for energy. Finding possible answers to these questions requires a systematic approach and a structured innovation strategy.

The Way Forward

Create a future competitive advantage tomorrow by defining your strategic direction today.

Making better decisions for tomorrow relies on an organization's ability to collect, understand, and act on innovation intelligence—the multitude of building blocks that make up an organization's innovation process.

Scouting the trends, technologies, startups, and other forces of change that are shaping your industry is a crucial first step in this process. But turning this information into innovation intelligence, and subsequently into action, requires additional steps and capabilities that fall within Foresight and Strategy.

Taking Trends & Technologies to Opportunities

1. Discover ITONICS Trends
2. Build Internal Consensus
3. Develop Pictures of the Future

1. Discover ITONICS Trends

Supplement the insights gained in this industry-relevant technology report with an immersion into the trend landscape.

Get started by exploring the ITONICS **Teaser Trend Radar** displaying the elements that are most relevant to your industry.

For a full view of the trend landscape, our **Where to Play 2021+ Trend Report** contains the complete ITONICS Trend portfolio, presenting 90+ Trends with real-life inspirations and rich analysis.

DOWNLOAD NOW

2. Build Internal Consensus

In establishing **Where to Play**, it is essential to gain consensus and raise alignment within your organization. This can be achieved through a process of collaborative evaluation. Invite internal stakeholders and experts to participate in rating elements—trends, technologies, scenarios, opportunities, etc.—based on unique industry- and company-specific parameters.

When undertaken in the environmental scanning stage, an internal rating exercise helps empower teams with the consensus needed to ensure strategic relevance, strengthen buy-in, and act decisively.

ITONICS has provided the following internal rating criteria for organizations to consider for trends and technologies:

Technologies

- Technology Attractiveness: How high is the potential value of the technology?
- Internal Know-How: How much internal know-how does your business possess with regard to this element?
- Need for Action: How important is it that your organization take action with regard to this element?

Trends

- Business Relevance: How relevant is this element to your business?
- Strategic Fit: How well does this element fit into your organization's overall strategy?
- Need for Action: How important is it that your organization take action with regard to this element?

The ratings above are pre-set in the ITONICS Showroom. However, organizations can tailor rating criteria to align with their own set of needs and workflows.

3. Develop Pictures of the Future

It's not enough to identify the trends, technologies, disruptive startups, and other drivers of change that are relevant to your industry and organization. To develop an innovation strategy that remains effective beyond the time horizon of key drivers, organizations need to develop realistic and plausible pictures of the future in which these various drivers will unfold. This is done through a process of **scenario planning** and is the basis for discovering future opportunities upon which to act.

Scenario planning is a strategic tool commonly used by key decision-makers, innovation leads, and strategists to find focused foresight, grounded in dependable analysis. This equips them to anticipate exposures appropriately, evaluate innovation opportunities, and inform proactive responses.

What is a scenario?

In the context of business planning and strategy, a scenario is a postulated sequence or combination of events projected to take place that could hold relevance to an organization's future state.

Developing plausible, actionable scenarios requires a systematic approach and organizational participation. It builds on the internal rating exercise, which serves to identify those trends and technologies that hold the greatest strategic relevance and potential. From here, your organization must derive the underlying drivers that are influencing its business environment and extrapolate the different trajectories each driver could take.

Plotting these trajectories against one another and engaging your team's collective and creative input reveals multiple scenario narratives. While each narrative represents a possible future for which your organization may need to prepare, internal consistency and strategic objectives point to those scenarios that should be prioritized.

Your team should prioritize the scenarios they feel hold the most strategic relevance by asking the following two questions:

- Is this a future we hope to play an integral role in creating and shaping?
- Is this a future we hope to mitigate and avoid through thoughtful tactics?

The selected scenarios form a foundational springboard from which your organization can best derive and define clear opportunities—i.e., possible solutions or responses to the various scenario narratives. Use the **ITONICS Roadmap** to plot critical scenario events and develop a timeline of innovation activities required to explore the various opportunities ahead of the horizon in which they are set to occur.

In this way, scenario planning provides organizations with the information required to act on opportunities timeously—as well as the evidence needed to develop appropriate capabilities and assets, actively shape our world, and influence outcomes as they steer towards the future.

To further your innovation journey, all the Trends, Technologies, and Inspirations selected as most relevant to energy can be found on the ITONICS Innovation Platform using the saved filter: **Energy**.

The ITONICS solution supports end2end innovation management, from environmental scanning and trend and technology management to building internal consensus and roadmapping.

REGISTER

About ITONICS

We build AI-powered SaaS to innovate, grow, and disrupt.

Our data-driven software platform helps organizations around the globe to identify emerging technologies, trends, and market potentials and translate them into powerful growth strategies.

Supported by artificial intelligence, companies can manage their entire innovation process in a modular software suite to efficiently achieve their business goals and remain future-proof.

Working with global teams to innovate new products, services, and business models, ITONICS professional services inspire, guide, and accompany organizations on their innovation journey. With more than 115 experts on four continents, we support innovation leaders such as adidas, AUDI, CISCO, Intel, Johnson & Johnson, and SAP.

As a strategic partner to key market players across all industries, we systematically advance the topics of innovation, strategy, and digitalization.

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What's Next

Turn Innovation Intelligence into Action

Your digital toolbox for game-changing innovation	Free access to inspiring insights & content updates	Dependable thought leadership & advisory services
▪ Industry-specific Trend and Emerging Technology Radars ▪ Strategic Roadmaps that guide you into the future ▪ Lean Portfolios to manage ideas, technologies, projects, and opportunities	▪ Access to 6 million+ signals to uncover insights at large scale ▪ 90+ Trends, 85+ Emerging Technologies updated annually ▪ 7,000+ freshly curated inspirations maintained	▪ Free innovation maturity assessment ▪ Exclusive access to COFIM Masterclass content ▪ Access to our international innovation community

You can find us around the globe

ITONICS is a leading SaaS provider of systematic innovation management. The ITONICS Innovation OS combined with a systematic framework to steer innovation efforts helps companies to identify emerging technologies, trends, and market potential and to translate them into customized growth strategies.

With more than 150 experts worldwide, we support innovation leaders such as adidas, AUDI, BMW, CISCO, Intel, Johnson & Johnson, and KPMG.

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All references and sources cited in this report are available upon request.