Future Cleantech Festival 24

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Future Cleantech Priorities

FCA Future Cleantech Architects

fcarchitects.org

FCA Future Cleantech Architects

Co-hosted by

United Nations Climate Change · UNIDO United Nations Industrial Development Organization · iTPO · IRENA International Renewable Energy Agency · MISSION INNOVATION · European Innovation Council

2024 Festival Impressions

So this festival brings together policymakers, academia, as well as financials and investors. And this is super important as all of these stakeholders need to work together to have a more ambitious plan as they go forward."

Bhava Dhungana
Team Lead Climate Technology Sub-division
UN Climate Change

The European Commission is a complex system, where being a co-host of something is not easy. So we started to come here to FCA as a co-host because we are really convinced, and this is what is happening, that we are able to reach in one event most of the stakeholders around energy."

Francesco Matteucci
EIC Program Manager
European Innovation Council

It is all about bringing people together to talk about things in a really dynamic way. The sessions are all completely varied, so for one moment you could be talking about the specifics of grid storage and in the next moment you could be talking about disruptive innovation in the highest level. [...] I think that having it in this setting is absolutely fantastic because it is just so conducive to bringing people out of their comfort zone, to really talk about the cutting-edge things that need to be talked about in person."

Dr. Eleanor Webster
Head of Secretariat
Mission Innovation

What is really great about the Future Cleantech Festival is that it brings together complementary perspectives that aren't usually to be found in the same room in an informal setting really."

Johannes Lohmann
Executive Director
Pollination

Table of contents:

Driving Cleantech Innovation. Together.

When developing the chapters for this year's festival, it did not take us long to agree that we wanted results to be specific and tailored to the hard-to-abate sectors.

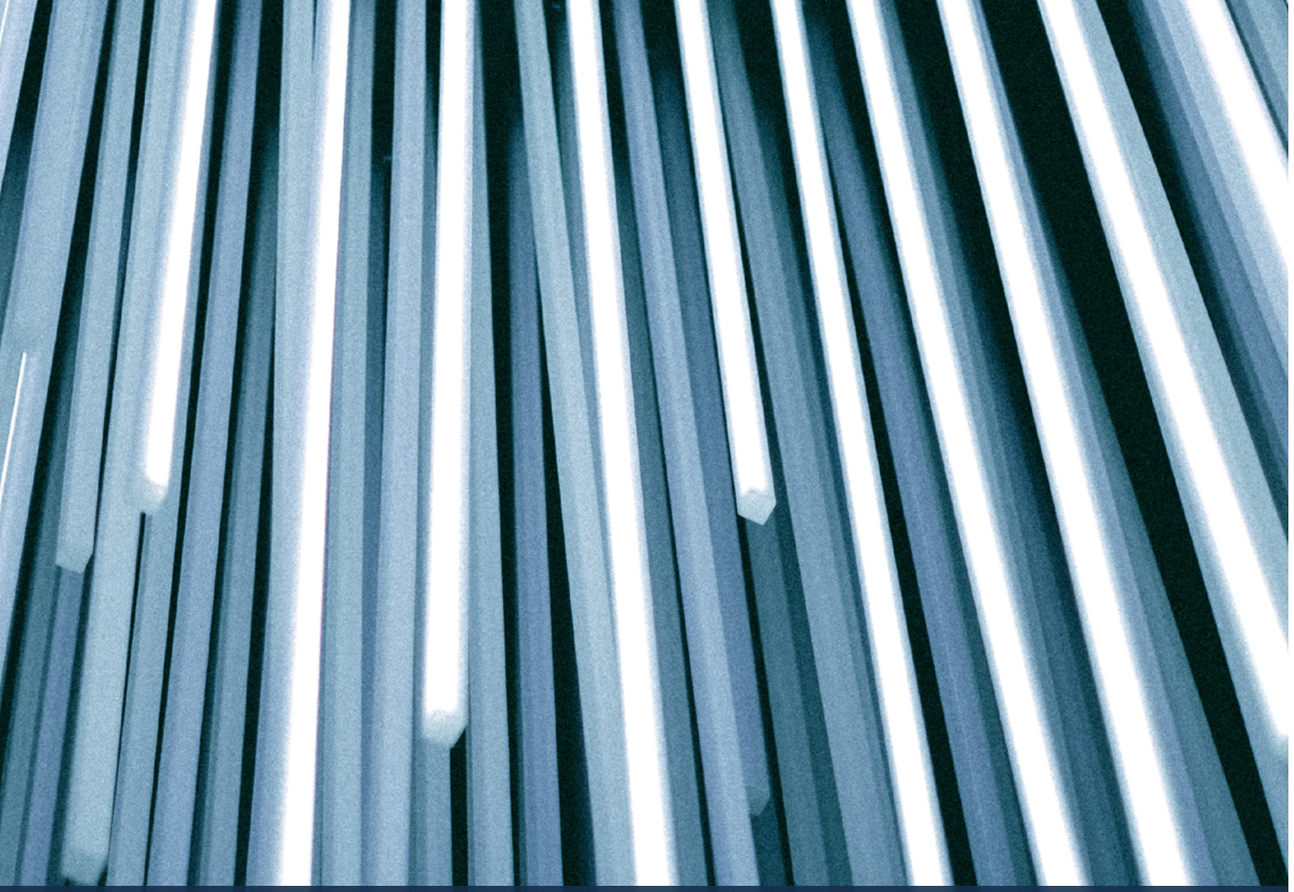
While our team works on technical analysis and solution pathways all year, a festival provides a special opportunity. As always, we target industry sectors with a large contribution to global warming — and technical solutions that are oftentimes still in their infancy. But unlike usually presenting results to political decisionmakers in Brussels, or at a multinational conference like COP, this time we took over an industrial town and combined technical discussions and policy approaches with on-site visits and many industry representatives.

It was an honor to once again team up with our co-hosts from UN Climate Change, UNIDO ITPO Germany, and to win highly relevant new co-hosts such as the European Commission's Innovation Council (EIC), the International Renewable Energy Agency (IRENA), Mission Innovation, or the Bonn Institute. Please find our takeaways and policy priorities on the following pages. Hopefully, they provide inspiration (and some guidelines) to your work. Looking forward to catching up at a Future Cleantech event soon,

Best Regards,

Dr. Peter Schniering

Founder & CEO, Future Cleantech Architects



Innovation

To achieve global climate goals, a diverse array of innovative cleantech solutions must be deployed across sectors such as energy, transport, and construction.

Simply scaling up existing cleantech will not be sufficient to reach net zero. For instance, high-temperature processes above 400°C account for half of industrial heat demand, and solutions to decarbonize this are still lacking. The global cleantech manufacturing and innovation landscape is highly competitive and is currently heavily dependent on external sources for critical raw materials and sustainable fuels. Developing disruptive innovation is essential for maintaining competitiveness and independence, and will both help transform existing markets as well as creating new ones.

At the EU level, the European Parliament elections in June 2024 will shape the EU's political direction and policies for the next five years. The outcome of these elections will significantly influence the future of the European Green Deal and the development and uptake of cleantech in the EU. The European Green Deal, launched in 2019, aims to make the EU climate-neutral by 2050. This ambitious initiative has led to an overhaul of the EU's climate and energy legislation through the Fit-for-55 legislative package, setting ambitious targets for emission reductions and promoting cleantech. The package aligns with the 2030 climate target of reducing net greenhouse gas emissions by at least 55% compared to 1990 levels.

Key takeaways

1

Urgent ambitious implementation at national level:

- After the adoption of ambitious global and European targets, the focus must now shift to implementation at the national level, especially through National Energy and Climate Plans (NECPs) and Nationally Determined Contributions (NDCs). This requires ambition, coordination, investment, and policy adjustments at the national level.
- In the EU, Member States must widely deploy cleantech, promote energy efficiency, and accelerate the development and deployment of renewable energy to meet the Fit for 55 targets. This includes that 5% of new installed capacity by 2030 comes from innovative renewable technologies.

2

Transformation of industries through disruptive innovation:

- Disruptive innovation must be clearly defined to ensure alignment among stakeholders. This definition should consider the specific context and goals of each country or region. Successful innovation requires a deep understanding of the national context and priorities.
- Governments should 'not do innovation but enable innovation' by providing a supporting regulatory framework and fast, reliable funding for innovative projects. This includes direct investment in companies as well as support for start-ups.
- A cultural shift in the way we approach innovation and failure is necessary. Failure should be seen as an important aspect of the development process. Public, private, and institutional investors should be willing to take calculated risks and mitigate them.

3

Investment in security mechanisms:

- Public guarantees and risk-sharing instruments from entities such as the European Investment Bank are needed to de-risk cleantech investments and catalyze more private investment into high-risk cleantech ventures.
- Full-scale EU-level venture capital funds dedicated to cleantech could provide additional investment security, as could support from national disruptive agencies.

4

Creation of a level playing field:

- EU Member States still subsidies fossil fuels (including with EU money) which hampers the creation of a true level playing field for renewable energy to compete.
- EU-level taxation mechanisms or tax-break models should be created in order to match the simplicity and predictability of the United States Inflation Reduction Act (IRA)'s support to clean-tech development and deployment in industrial processes.

5

Promotion of research and innovation as well as auctions with non-price criteria:

- Successful cleantech development requires understanding and nurturing the entire ecosystem (incubator approach) - from R&D to scale-up to manufacturing.
- Green public procurement must be mobilized for innovative cleantech, incorporating non-price criteria such as resilience, innovation, and life-cycle assessment in public tenders to drive the development and deployment of cleantech.

Key takeaways

6

Focus on high-temperature heat:

- Natural gas has been a preferred fuel for various high-temperature industrial processes due to its high energy density, relatively low cost, and non-degradative material properties at high temperatures. Industries such as cement, steelmaking, glass production, ceramics, and chemical manufacturing have traditionally relied on natural gas for its consistent and efficient heat output. If there is a switch to renewable electricity, most heating costs will come from electricity. Therefore, the electrification of industrial heat could triple energy costs for some industries. Additionally, other factors influence the costs: the availability of biogas which may be limited, making thermal energy generation from electricity costly, while international competition from regions with cheap fossil fuels availability outside Europe poses challenges.

- Grid charges are often high, while renewable power itself is cheap. Current grids are quasi-monopolies and cannot match the growing electricity demand, which causes stress on transmission and distribution networks, while the high power and energy density of industrial demand means on-site renewable generation is often insufficient.

7

The critical role of journalism in communicating on climate change and policies:

- Effective communication is crucial in managing expectations and maintaining public support for ambitious climate policies. The transition to clean energy, marked by a significant shift from fossil fuels to renewable sources, presents a complex and challenging process. This transition is extremely challenging, not ``a walk in the park``.

- Journalists are pivotal in communicating about climate change, ensuring the accuracy of information and opinions in energy and environmental journalism, especially when addressing misinformation. News coverage of climate solutions must rely on accurate context, scientific baselines, and peer-reviewed evidence. Navigating the energy transition requires collaboration, expertise, and nuance. Communicating complex scientific information to various audiences requires embracing complexity, making it accessible, and providing transparency through citations and references. Journalists must be transparent, skeptical, and aware of their own biases when reporting on these issues.

- Finally, the role of journalism in the digital age is evolving, with social media platforms playing a crucial role in reaching diverse audiences. Building trust through transparency is essential, and journalists must adapt to the changing media landscape. The shift from traditional media to social media has transformed the way information is consumed, emphasizing the need for common ground in journalism, particularly in democratic contexts.

2024 Innovation Quotes

Disruptive innovation is moving beyond traditional forms of innovation. And it is not to say that traditional innovation is not beneficial but that non-traditional or more modern forms of innovation might be more beneficial in certain contexts."

Thibyan Ibrahim
TEC Chair
UN Climate Change

We need to ensure adequate investment in research and innovation, not least to create a robust pipeline of scalable market-ready technologies that can drive the green transition. (...) To remain the leading continent for sustainable industrial innovation, we need to continue to be a continent of industrial production."

Maroš Šefčovič
Executive Vice-President
European Commission

I would actually ask the Commission to set up a program where the national or the Member States are supposed to really end the subsidies for fossil fuels, because this is huge. For 2022, I think it has been 120 billion euros in subsidies all across Europe. So I think there is a huge potential and it levels the playing field.

Rebekka Müller
State Chairwoman NRW
Volt

My wish would be for realistic and honest communication about the transition to carbon neutrality, because it is a great project. It has a lot of prospects, but it should be communicated more clearly that it is not going to be a walk in the park. It is going to be very hard and there needs to be awareness of the effort that needs to be done.

Gregor Erbach
Head of the Climate Action Research and Tracking Service
European Parliament Research Service

Our Innovation Resources
Future Cleantech Architects

Future RD&D needs: Future Needs in RD&D Report - Future Cleantech Architects

Our recommendation of 5% for innovative renewables for the European Renewables Energy Directive's revision (RED III)

Rosalinde Van der Vlies
Future Cleantech Festival

Maroš Šefčovič
Future Cleantech Festival

COFFEE & CLEANTECH
Briefing policymakers on neglected sectors.

Our new series of 45-minute insightful and engaging technical briefings is aimed at providing EU policymakers and advisers in Brussels with a concise yet sufficient overview on technological innovations for decarbonizing the most neglected hard-to-abate sectors. Based on FCAs research and analyses, our Cleantech Analysts summarize the key facts and figures on some of the most challenging issues, such as decarbonizing cement production, bringing long duration energy storage to scale, and fast-tracking sustainable aviation.

Future Cleantech Priorities
Policy Recommendations

By focusing on low-hanging fruits, research and innovation, and leveraging existing and upcoming cleantech solutions, the EU can make significant progress in addressing decarbonization challenges.

1. Maintain ambitious climate goals:

Ensure the EU remains committed to the Green Deal and the Fit-for-55 package, aiming for significant emissions reductions across all sectors, particularly in energy, construction, and heavy transport (aviation and shipping), and leveraging cutting-edge research and innovative solutions to achieve the 2030 and 2050 climate targets.

2. Align EU industrial policy with the Green Deal:

Develop industrial policies that support the goals of the Green Deal and the Industrial Plan. This will enhance the EU's competitiveness in the global cleantech market through increased research and innovation, energy efficiency, alternative materials, and recyclability. The Industrial Plan should also incentivize the uptake of cleantech in industrial processes.

3. Reinforce policy and market mechanisms:

Advocate for ending fossil fuel subsidies across Member States to level the playing field for renewable energy. Implement non-price criteria in renewable energy auctions and public procurement to promote sustainability and innovation.

4. Support industrial decarbonization:

Implement financial guarantees to mitigate risks for industries transitioning from natural gas to electrification, adjust grid fee structures to reduce costs for industries using renewable energy making green power more economically viable, and explore the use of virtual Power Purchase Agreements (PPAs) – without grid fees - to secure clean energy at competitive prices for industrial users.

5. Strengthen R&D and innovation funding:

Prioritize funding for cleantech research and innovation by allocating more resources to Horizon Europe in the next programming period. Increase funding for the Innovation Fund and the EIC program to support a diverse range of technical solutions and fasten access to financing for cleantech startups.

6. Foster a robust cleantech innovation ecosystem:

Create policies that finance early-stage research, provide public credit guarantees for derisking investments into high-risk cleantech ventures, demonstration, and first-of-a-kind facilities, and support commercialization through venture capital funds and innovation loans.

7. Respond to global competition:

Develop strategies to counter the competitive pressure from regions with cheap fossil fuels, ensuring the EU remains a leader in cleantech, and promote international collaboration to build a comprehensive cleantech ecosystem, integrating all stakeholders from innovation to implementation.

8. Push for the urgent adoption of the revised Energy Taxation Directive at the European level and leverage private capital:

Tax fuels based on energy content and environmental performance rather than their volume, promoting the use of renewable and low-carbon energy products. Private capital should also be channeled to riskier investments in cleantech ventures, such as pension funds.

9. Facilitate community acceptance and stakeholder engagement:

Foster communities of energy, heat generation, and storage alongside potential industrial customers to strengthen partnerships and to leverage collective expertise and resources, drive cleantech development, and decentralize the grid.

10. Promote effective communication:

Manage public expectations and maintain support for ambitious climate policies, particularly through transparent, evidence-based journalism that can navigate the complexities of the clean energy transition and counter misinformation.

Currently, aviation and shipping together are responsible for ~5% of global annual CO_2 emissions and are the two largest emitters in the transport sector after road transport.

Air travel remains the fastest means of global transit and an essential enabler of touristic travel and trade, while shipping remains the most efficient and affordable means of global trade. The role of shipping and aviation will continue to rise in the coming years, as the global south rightfully develops and the world's population continues to grow, but the imperative to reduce their impact on the environment is clear.

Maritime shipping is crucial to global trade, offering an affordable and efficient means of transporting goods. Over 80% of traded goods by volume annually are delivered by shipping. However, with the sector highly dependent on high-polluting bunkering fuel such as Heavy Fuel Oil (HVO) and marine diesel, it is also responsible for ~3% of Greenhouse Gas (GHG) emissions annually. Serious efforts into the development and deployment of alternative fuels is crucial to help mitigate this sector's emissions. Regional and international efforts are necessary to decarbonize this crucial sector of our economies and achieve net zero by 2050.

The aviation sector is responsible for ~3.5% of the global warming effect on the planet when its non-CO_2 effects are considered. Aviation's largest hidden emissions come from contrails, which alone contribute to more than 50% of the sector's impact on global warming. While technologies to decarbonize the sector are spoken of often, from electric aircraft to e-fuels, the sector is still highly dependent on conventional jet fuel. Even less attention is paid to contrails, a low-hanging fruit that can be mitigated through flight rerouting and sustainable aviation fuel (SAF) uptake.

Transport

Key takeaways on **Shipping**

1

Alternative fuels are key to decarbonizing shipping but remain expensive:

Most of the alternative fuels for maritime applications, such as ammonia and methanol, will be dependent on green hydrogen, which makes up 80%-90% of their costs. Additionally, the cost of green hydrogen is dependent on electricity prices and is unlikely to drop significantly in the near future. This is exacerbated by the low price of shipping fuel, which is usually some of the lowest-rated fuel, adding to the cost disparity. The carbon abatement cost of switching from low-sulfur fuel oil to green ammonia or green methanol is in the range of $600-$800/ton. This begs the question of what policy levers are needed to accelerate the deployment of green fuels and technologies.

2

A rethinking of infrastructure is needed:

The transition to alternative fuels requires infrastructure adaptation:

- A massive scale-up in production and supply of alternative fuels such as hydrogen, green ammonia, and green methanol from today's levels is needed.
- Pressure will increase on the grid as additional electricity capacity will be needed with the shift to these alternative fuels.
- Infrastructure and materials must be reimagined to suit new criteria from these alternative fuels, such as ammonia's storage and toxicity.
- Ports are crucial to providing the infrastructure to support the early stages of the sector's transition, but they will need restructuring to adapt to new fuels with more demanding safety requirements.

3

Startups working on alternative fuels face major roadblocks:

Innovation in alternative fuels manufacturing is essential to decarbonizing shipping, but technologies must be brought to scale and costs must come down. To cross the valley of death, startups need access to feedstocks such as clean hydrogen and sustainable CO_2, support to scaleup faster, and accelerated funding schemes to begin work on projects faster.

4

Uniform certification and sustainability standards are crucial:

The trade of green fuels between producer and consumer regions necessitates further collaboration amongst multiple actors, where proximity and mode of transport influence the final costs. This is crucial for the EU, which has historically been a net importer of bunkering fuel and may continue to be an importer of alternative fuel. Building relationships with trusted partners and establishing uniform regulations and certification for the development and trade of eligible alternative fuels, that adhere to a uniform standard of sustainability based on lifecycle greenhouse gas (GHG) emissions amongst other criteria, will be crucial to the future trade of clean fuels.

Key takeaways on **Aviation**

1

The two solutions to tackling contrails:

There are two main routes to reduce contrail formation. The first is through the utilization of Sustainable Aviation Fuels (SAFs), which have lower aromatic content that is directly linked with contrail formation. Using SAFs on contrail prone flights could help reduce their formation. The second approach is to reroute flights to avoid the regions with peak atmospheric conditions for contrail formation.

2

Balancing contrail reduction, operational feasibility, and environmental impact:

- Prioritizing SAFs for contrail prone flights is challenging as it will require an overhaul of the way fuelling systems at airports work today. Additionally, SAFs remain in limited supply and are restricted to a maximum 50% blend with conventional fuel per flight due to engine safety considerations pertaining to minimum aromatic content. Even if in the future 100% SAF operated flights are possible, SAFs alone cannot eliminate contrails completely.

- Flight rerouting provides a pathway with one of the lowest carbon abatement costs with a price of 0.5$/ton CO2. Approximately 10% of all flights are prone to contrail formation. Even though rerouting requires additional flight time and fuel burn to avoid ISSRs, these are mostly small diversions resulting in minimal added fuel burn but significant environmental savings from contrail avoidance.

3

The roadblocks to addressing contrails:

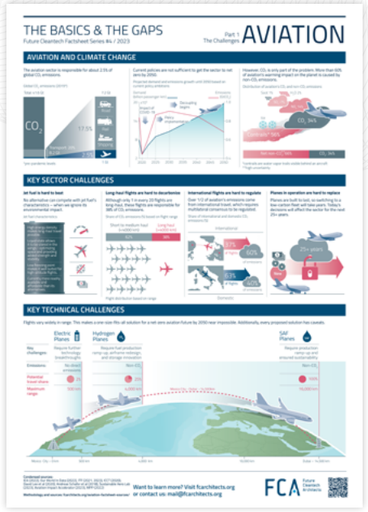
There is currently no business case for reducing contrails as it requires additional fuel burn, albeit a minimal amount, and is not included in science-based targets. The primary focus remains on CO2 emissions. If contrail avoidance doesn't deliver economic savings, tax benefits, or equivalent carbon credits, there is little incentive for the sector to tackle the problem.

4

A systems thinking approach to contrails mitigation:

A holistic approach to addressing contrails is needed. Improvements in weather monitoring systems, predictions, and validation are key. Additionally, air traffic management must be brought on board to work with pilots and develop a standard operating procedure for contrail avoidance, which includes aspects such as identifying contrail prone flights and when to reroute. Finally, pilots must be brought around to tackling contrails, as they've been instructed for decades to fly efficiently and minimize fuel burn, and that message is changing with the need for rerouting.

Our Aviation Resources
Future Cleantech Architects



Factsheet on Aviation

Aviation EU Policy Brief

Aviation Policy Brief June 2024

Future Cleantech Priorities
Policy Recommendations

1. Maintain the momentum:

The European Green Deal has been a momentous achievement; however, the hard work is just starting to meet ambitious targets within the EU. Rather than slowing down, policymakers must maintain the momentum as revisions of important legislation and increased funding support for innovation will be crucial to achieving carbon neutrality by 2050. Regulation must also expand to include aviation's hidden emissions and address contrails.

2. Create a business case for alternative fuels:

The cost differential between conventional and alternative fuels in the shipping and aviation sectors remains high. Some of the most expensive fuels remain the synthetic fuels, such as green methanol for shipping and synthetic jet fuel for aviation, yet they are the only scalable and sustainable fuels available.

- **Increase funding and support for research, development, and innovation:** Synthetic fuels are dependent on green hydrogen costs and availability. Investment and support must focus on innovation, technology breakthroughs, and decreasing the cost and availability of clean electricity, which is the major barrier to the scalability of both hydrogen and hydrogen-derived synthetic fuels. A great start is the European hydrogen bank auction that awarded ~ €720 million to several renewable hydrogen projects across the EU.
- **Facilitate entry of new players and startups:** Beyond green hydrogen, startups working on innovation and alternative fuels need facilitated permitting to scaleup faster, and reduced lead times for grants to begin work on projects faster, as it can take years between receiving and then finalizing a grant, wherein no work can be completed. Access to funding and faster permitting can be the difference between failure and success for a new player. A great start is the EU's innovation fund and the European Innovation Council but partnerships between startups and incumbents could be supported further.
- **Encourage partnerships along the value chain:** Stakeholder collaboration from across the value chain, from the producers to the customers, will be crucial to overcome the economic challenges in these sectors. Private sector involvement, such as through the First Movers Coalition, can help reduce the financial burden and de-risk innovation. In many cases part of the green premium will have to be passed on to the consumer and it is crucial to raise awareness amongst consumers on the importance of alternative fuels.

3. Adopt market-based measures:

The polluter-pays principle must extend to aviation and shipping. These carbon-pricing mechanisms, if implemented effectively, can spur emissions reductions by helping to close the cost gap between alternative and conventional fuels. Additionally, carbon pricing mechanisms can help incentivize oil companies to increase alternative fuels production. Revenue from carbon pricing should be reinvested into the sector to stimulate innovation and further development and deployment of alternative fuels.

4. Introduce effective regulation:

Carbon pricing is not a silver bullet, so additional, bespoke regulation is essential in cases where costs need to be passed on to the consumer. For example, in aviation, a frequent flyer levy could be implemented where a progressively increasing tariff is applied based on the number of flights a passenger takes a year. Revenue from this tariff can be reinvested into emissions reduction efforts while minimizing the impact on lower income households that travel less frequently. Emission reduction efforts must also encompass all aviation segments, including business/first class and private jets, whose per capita emissions are many times higher than other flyers. In shipping, bespoke mandates to improve energy efficiency should be implemented so that the limited supply of clean fuels can be effectively delivered to the market.

5. Implement ambitious, yet fact-based, targets:

For targets to be effective at minimizing emissions, they must be ambitious. However, these targets must be rooted in facts and science, and in the case of alternative fuels, must consider cross-sectoral competition for limited resources. This is due to the limited availability of renewable energy and potential over-reliance on imported fuels. The targets in ReFuelEU Aviation and FuelEU Maritime on their own are not enough to reach net-zero by 2050 but are a good starting point to incentivise the use of sustainable and scalable fuels. These targets should at the same time be clearer on feedstock requirements, for instance availability of green hydrogen and electricity, to produce alternative fuels.

6. Introduce contrail mitigation efforts:

Contrail mitigation must become part of emissions reductions strategies to incentivize the sector to start addressing this so far still neglected topic. Public awareness is key so that contrails' warming impact is better understood and the need to combat contrails is accepted. Political resistance needs to be overcome so that the conversation with policymakers shifts from educational on what contrails are and why they matter to actionable on how to mitigate said impact and what policy levers are needed, such as incorporating rerouting procedures into the Single European Sky.

7. Strengthen International Cooperation and Standards:

International trade and travel play a significant role in both the shipping and aviation sectors respectively, and consequently, contribute to a large portion of emissions.

- Most countries, in the Global North in particular, should implement regional or international rules to ensure both sectors decarbonize as fast as possible. Discussions at a global level are key for countries to align on the same rules and regulations to maintain a global level playing field.
- When it comes to alternative fuels, there is a need to establish a global and auditable certification system.
- The targets of the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) should be higher, more ambitious, and clearer. ICAO's long term aspirational goals should expand to include non-CO2 effects, and both should enforce concrete emissions reduction policies.

Concrete is the literal building block of the modern world, and the production of cement to make concrete contributes around 5% of global greenhouse gas emissions, or 7% of CO_2 emissions.

Cement-making is viewed as one of the toughest hard-to-abate sectors, as 60% of its emissions come from the chemical reaction at its core, and even the remaining energy-related emissions are at such high temperatures (up to 1450°C) that few competitive or scalable low-carbon options exist today.

Beyond the technical challenge, decarbonizing cement is difficult economically: a highly competitive market leaves slim profit margins to reinvest in R&D; plant lifetimes are long due to high CAPEX, slowing down the deployment of newer technologies. It also requires a systemic paradigm change of the construction industry beyond the cement plant.

Nevertheless, many policy options can help to unlock some of these barriers and set the industry on the path to Net Zero. To do so, a holistic approach to the whole construction value chain provides more leverage than focusing just on the level of the cement plant.

Construction

Key takeaways

Structural Efficiency

1

Less is more:

There is vast and neglected potential for structural efficiency to significantly reduce demand for construction materials, whether concrete, steel, or timber.

2

We need an equivalent metric to energy efficiency but for construction materials:

Like switching from incandescent lightbulbs to LEDs, it's estimated that current buildings are only 2% structurally efficient in practice compared to the theoretical optimum, and that cutting emissions per building by a factor of 4 through structural efficiency is already technically feasible today.

3

We cannot improve what we cannot measure:

We need to systematically collect data on structural efficiency for buildings and report this, just like we measure the energy efficiency of all appliances. Engineers can then be asked to deliver not just a safe building, but also an efficient one.

4

Today's material inefficiencies are a direct consequence of cost ratios...

...skewing towards cheap materials (thanks to cheap fossil energy) and high labor cost, which incentivizes overusing material. Historically, the opposite was true and efficient structures were the norm (e.g. see how much lighter the vaulted structures of cathedrals are compared to the thick flat slabs of modern building floors). This can be fixed by going back to the principles of structural efficiency, while using modern tools (such as algorithms, robotics, and off-site manufacturing with on-site assembly) to reduce labor costs and construction times.

5

We need to shift to a circular economy:

Construction materials alone make up 40% of European waste streams. The sector has a long way to go in reducing inefficiencies and minimizing waste, focusing on dismantling for reuse, rehabilitating structures to extend their lifetimes, optimizing construction through structural efficiency, and providing lower-carbon alternatives for new cement usage.

Carbon Sequestration

1

CCS does not negate direct emissions reductions:

Of all industries, cement-making is the poster child for carbon capture and storage (CCS). However, even for this industry, CCS is no cause for business as usual: given its high cost (around 180-200 €/ton today and potentially 110-150 €/ton in the future), emissions reductions (e.g. clinker reduction) should always be the first priority; they also enhance the feasibility of CCS by reducing the volumes of CO_2 to be addressed, so the two strategies go hand in hand.

2

A complicated cost picture:

Even with future cost reductions, CCS for cement-making is costly, roughly doubling the cost of cement. However, even with a high premium on the cost of "green" materials, the impact on the total cost of the final building is actually low, so the wider market should be able to absorb this premium.

3

Location is key:

The right geology is necessary to sequester carbon, and storage sites should be as close as possible to industrial emitters to reduce pipeline costs, hence why onshore is around 90% cheaper than offshore. Yet, there is a huge disparity in planned storage sites, in part from public reticence to onshore sites, with 90% of plans in the North Sea and very little in southern Europe.

4

CCS is not a single challenge but rather a whole value chain to be developed...

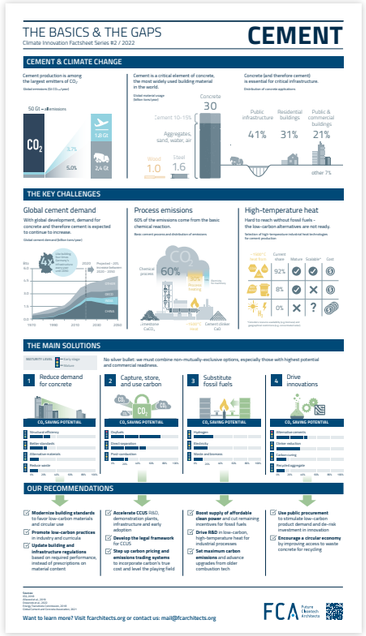
...requiring a business case for all partners and coordination across companies and countries to build the required infrastructure (e.g. pipelines from countries like Switzerland and Austria would need to cross Germany to access storage sites). A regulatory framework is urgently needed to give the industry some security in developing this infrastructure.

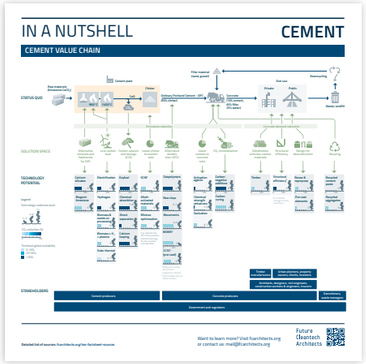
5

Mineralizing CO_2:

Geological storage is not the only option; mineralizing carbon dioxide into rock is a permanent and scalable form of sequestration (e.g. using demolition concrete, the world's largest waste stream).

Resources
Future Cleantech Architects





Cement Value Chain

Factsheet on Cement

Future Cleantech Priorities
Policy Recommendations

1. Switching from prescriptive to performance-based standards:

Current prescriptive standards are simple to use but limit innovation, as low-carbon cements and concretes (or other materials) might not comply. Performance-based standards, while requiring some adaptation for industry to follow, allow more solutions to compete fairly and thus open up the market to innovation. Beyond lower-carbon materials, standards should also incentivize structural efficiency of buildings in order to reduce material usage and enhance the sustainability of the entire building lifecycle.

2. Incentivizing the use of sustainability criteria in public procurement:

This also includes setting clear sustainability criteria and quotas for construction projects funded by public money to create a market pull for green products and cleantech.

3. Training the competent authorities:

Green public procurement and performance-based standards have massive potential, but require building administrative capacity at the local level for effective implementation.

4. Support innovative technologies:

Carbon Contracts for Difference (CCfDs) are a modern grant scheme that de-risks low-carbon technologies and helps firms set up large industrial plants by using auctions (which foster competition) and providing hedging by granting firms a fixed CO_2 price for business calculations. The German CCfD program is initially focused on sectors excluding cement, but aims to open for the cement industry in the next auction round. Conditions for scaling CCfDs beyond Germany to other Member States and/or the European level include:

- Ensuring a two-way mechanism (not just subsidies) where the government can receive payback if market conditions change.
- Addressing both capital (CAPEX) and operational (OPEX) costs to stimulate large scale investments.
- Building ministerial capacity across EU countries to implement CCfDs effectively, given the large team working on it in Germany.

5. Make the disclosure of CO_2 emissions intensity mandatory:

Transparency on the CO_2 intensity of cement and concrete products is crucial for driving demand for low-emissions options in infrastructure projects where hesitancy remains. The upcoming Construction Products Regulation (CPR) will require producers to provide CO_2 content information for products, enabling a „green cement" informed market with proper procurement policies and sustainability criteria.

6. Carbon Capture, Utilization, and Storage (CCUS) and Carbon Dioxide Removal (CDR) are critical components:

Rather than relying solely on emitters who incorporate CCUS technologies in their cement production facilities, obligations must also lie with fossil fuel producers and importers to drive CO_2 storage and related infrastructure investments. There is a pressing need for clear policy signals and targets for carbon removal deployment to drive investments, as current proposals lack clarity. A compliance market obligating companies to compensate for residual and historical emissions could create demand for CDR. These technologies could be included in future auctions to also test their feasibility and effectiveness in real-world conditions.

Future Energy Systems

The energy transition requires more than just increasing renewable energy generation; it needs enhancing flexibility within the power system.

As the energy transition unfolds, clean and flexible energy sources will be paramount in complementing intermittent solar and wind energy generation, ensuring a future resilient energy system without relying on gas turbines or polluting energy generation pathways. Clean firm power, such as enhanced geothermal, hydropower and concentrated solar power (CSP) with integrated storage, provide a reliable and consistent electricity supply from low-carbon sources, crucial to complementing the increased penetration of intermittent renewable energy sources like wind and solar into the power system.

Furthermore, the exponential growth of wind and solar energy that the world has experienced over the last two decades is starting to spur an equally dramatic need to invest in the development and deployment of energy storage facilities. During recent years, there has been a predominant emphasis on short-duration storage facilities utilizing lithium-ion battery technology, which have a typical discharge duration up to a few hours. However, there are energy storage technologies capable of supplying heat and power for much longer periods of time. These facilities will be needed for the energy transition to be successful, making up for long periods of low renewable generation, which span from days and weeks to seasons.

Key takeaways

Clean Firm Power

1

Clean firm power integration:

The increased penetration of variable renewable energy has created challenges for power systems balancing. Consequently, some countries are relying on clean firm power from neighboring countries for grid stability (e.g., Germany partially relying on nuclear from France). To address grid balancing issues and reduce reliance on energy storage, it is essential to diversify intermittent renewable sources and integrate clean, dispatchable firm power such as hydropower, geothermal, and concentrated solar power (CSP1). For instance, developing hydrokinetic power plants and other decentralized forms of power generation can alleviate the load on central grids.

2

Grid infrastructure:

Adopt a holistic approach to enhance grid infrastructure, ensuring efficient energy transport from generation site to consumption areas. This includes strengthening interconnectors between countries to manage a higher share of renewable energy and enhance grid security. Enhanced grid infrastructure will support a more robust and interconnected energy network, facilitating the transition to a sustainable energy system.

3

Potential role of hydrogen in the power sector:

Hydrogen is an indispensable feedstock for industrial applications such as fuels and fertilizer production. Clean hydrogen should be prioritized in sectors where it will deliver significant climate benefits. However, using hydrogen for daily electricity generation faces significant challenges due to the low round-trip efficiency and correspondingly high costs. For instance, producing green hydrogen from renewable electricity and then converting it back to electricity later wastes 75% of the original energy. Additionally, generating hydrogen from natural gas, even with high carbon capture rates and strict methane emissions control, only achieves a 50% emissions reduction compared to unabated natural gas power plants. Furthermore, there are significant costs associated with hydrogen infrastructure requirements that would contribute to the total carbon abatement costs. By contrast, hydrogen might play a more useful role specifically as a form of long-duration energy storage for the power sector. This application can help balance supply and demand over longer periods of seasons or years, supporting the integration of intermittent renewable energy sources.

Energy Storage

1

Role of energy storage technologies:

Energy storage technologies will play a critical role in addressing the challenges posed by increased renewables penetration into the power system. Beyond Li-ion batteries, which are limited to a few hours' worth of storage, the available storage technologies are very diverse, ranging from electrochemical (e.g. redox flow), to thermal, mechanical (e.g. pumped hydro), and chemical (e.g. hydrogen). This diversity and the technologies' unique respective characteristics are crucial to fully cover the multi-faceted needs of grids, from intra-day storage (e.g. day/night cycles with solar) to longer durations of days, weeks, and seasons (e.g. the dreaded "Dunkelflaute", long periods of low wind and solar). There is no one-size-fits-all technology here.

2

Lack of positive business case for energy storage technologies:

To incentivize the development and deployment of energy storage, it is essential to create market demand and develop innovative financial models that reward investment and de-risk projects. Strong policy support and a combination of public and private funding are necessary to ensure the economic viability of mid to long-duration energy storage solutions.

3

Research and development needs:

Investing in R&D is crucial for advancing technology innovations such as high-temperature thermal storage. These innovations require further investment to achieve high technology readiness level (TRL) and increase market penetration. Continued R&D, supported by cross-border collaborations, is essential for advancing these innovative solutions and ensuring their successful integration into the energy market.

4

Integration of thermal energy storage into industrial decarbonization plans:

Thermal energy storage can unlock cost-effective decarbonization potential for the industrial sector's heat demand. Energy stored as heat can be converted back into electricity, or used in high-temperature processes, delivering high-energy density and efficiency. Examples of thermal storage materials include molten salts, rock, graphite, and silicon. To fully benefit from thermal energy storage in industrial applications, challenges such as commercial scaling of prototypes need to be addressed.

Key takeaways

5

Capabilities development in energy storage & foster partnerships across the value chain:

Universities and technical institutes should develop specialized educational programs to prepare the next generation of engineers, scientists, and skilled laborers in energy storage. Public awareness campaigns can highlight the importance and benefits of energy storage technologies, ensuring their inclusion in energy systems design. Additionally, fostering collaboration between academia and industry, and promoting public-private partnerships can help accelerate energy storage adoption.

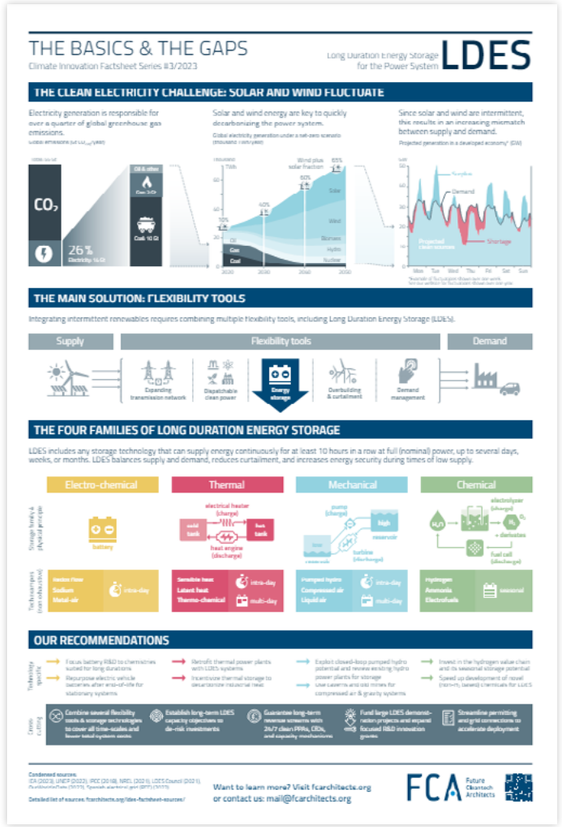
6

Niche applications as a stepping stone to widespread deployment:

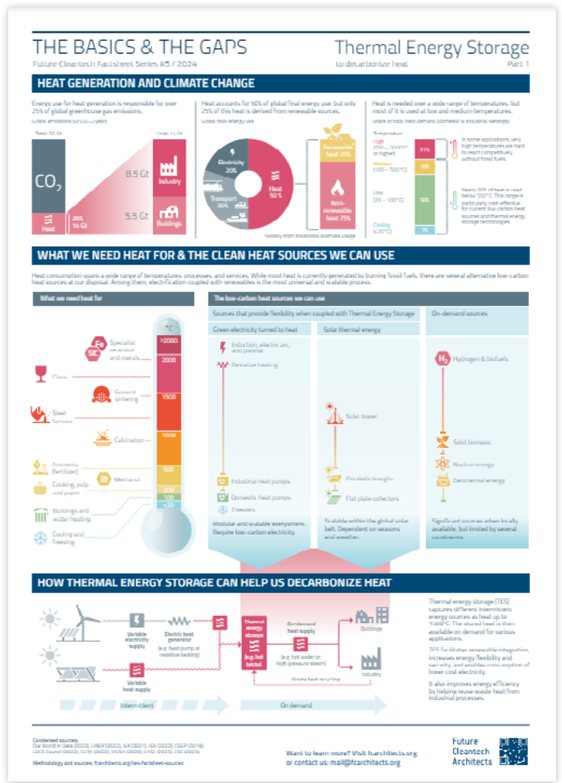
The case for energy storage is already strong in certain applications, such as in isolated regions or communities relying on diesel generators. Targeting these is a natural first step for the nascent energy storage industry and paves the way for commercial experience and cost reductions which can then spur wider deployment in global energy systems.

Resources

Future Cleantech Architects



Factsheet on Long Duration Energy Storage



Factsheet on Thermal Energy Storage

Future Cleantech Priorities
Policy Recommendations

1. Adopt a system-wide approach:

Decarbonizing the power sector requires a comprehensive strategy that assesses all components of the future energy system, which goes beyond expanding intermittent renewables. The successful design of the future energy system should identify efficient approaches to decarbonizing the grid and include an ecosystemic strategy. This strategy should integrate flexibility tools such as long-duration energy storage (including thermal storage for heat applications), digitalization, clean firm power, and enhanced grid infrastructure.

2. Remove permitting barriers and accelerate permitting processing:

Governments should invest in internal administrative capacity to accelerate permitting processes and remove barriers hindering clean energy development. The current permitting process is widely reported as inefficient and unclear for start-ups and companies looking to commercialize their technologies. Additionally, bureaucratic barriers cause unnecessary delays in project permitting, creating roadblocks for investors and hindering the adoption of these technologies.

3. Leverage digital tools to improve grid operation:

Integrate state-of-the-art digital tools to enhance grid operability and integration of renewable energy, avoiding the need to overbuild new grids. Grid operators should focus on developing future-proof smart grids. Currently, there is a lack of incentives for innovation, decentralization, and efficiency, which needs to be addressed to drive the adoption of smart grid technologies. By leveraging digitalization, we can create more responsive and resilient grid systems that efficiently manage energy flow and support renewable energy sources.

4. Create market demand for flexibility tools:

Incentivize energy storage solutions to complement renewable energy expansion. To ensure a stable revenue stream, increasing demand for renewable energy and 24/7 clean energy Power Purchase Agreements (PPAs) is crucial, along with developing energy storage solutions to balance supply and demand. Additionally, it is important to design energy markets that abolish perverse incentives that punish flexibility tools, such as double taxation of energy storage facilities. The energy market design should value and reward flexibility and energy storage solutions, thereby encouraging investment and innovation in these areas.

5. Invest In augmenting know-how inside institutions for effective policy design:

Investing in enhancing institutional capacity by training civil servants, judges, and prosecutors on energy laws to ensure well-informed decision-making throughout the policy chain. Policymakers should actively engage with both innovators and established players to foster a dynamic and adaptable policy environment. Decentralization is crucial for the energy transition, with a focus on local solutions and community engagement. Participatory budgeting can involve the public in decision-making processes, ensuring policies reflect local needs and diverse perspectives, thereby creating more effective and inclusive energy strategies.

6. Adopt mechanisms to de-risk investment in new technologies:

To support industrial decarbonization and complementary solutions to grid expansion, implementing mechanisms to de-risk investments in new technologies are essential. Policy measures such as public guarantees, increased funding for R&D to advance technological maturity, and subsidies to reduce the financial burden on companies investing in energy storage and flexibility technologies can provide a safety net to investors. These mechanisms should support first-of-a-kind projects to reduce technology costs. These measures lower risks, support the adoption and scaling of new technologies, and encourage innovation in the energy sector (e.g., advancing the market penetration of thermal and energy storage technologies). This de-risking strategy pays off later by creating new markets both within Europe and outside via technology exports, increasing competitiveness.

7. Leverage member states' learnings:

European Member States should disseminate successful power system decarbonization learnings and approaches and integrate them in other areas. This includes effective approaches to project implementation, streamlined permitting processes, and innovative financing.