GLG

OCTOBER 2022

A RECKONING FOR RENEWABLE ENERGY

Trends and Industry Insights

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INTRODUCTION

The war in Ukraine and the climate emergency have created a reckoning for renewable energy. In 2021, global renewable electricity generation rose by nearly 7%, reaching 28.7% in market share of total electricity generation with a growth of 0.4%. The modest growth was due to soaring demand that came with the COVID-19 economic rebound, but droughts and low winds in parts of the world have hindered hydropower and wind generation.

While electricity generation has made substantial progress in recent years, replacing fossil fuels with solar, wind, and hydro, the current growth rate is falling short of meeting the net zero target by 2050. But even more worrying are other sectors, including transportation, manufacturing, and heating, where the use of renewable energy is lagging behind other industries. Accelerated efforts from the public and private sectors are needed if countries are to achieve energy independence and the net zero target.

Renewable technologies across the board must be deployed more quickly.

Renewable technologies across the board must be deployed more quickly. Yet unresolved issues differ from sector to sector and from region to region. In this eBook, we have compiled a handful of commentaries with expert insights into the current state of renewable energy development, offering a broad and insider perspective into this important market that will soon impact all our lives.

The first article, **Low-Carbon Fuel Alternatives in the Maritime Industry**, looks at marine transportation and the challenges shipping companies face to decarbonize, and the different kinds of low-carbon marine fuels with the potential to transform the industry.

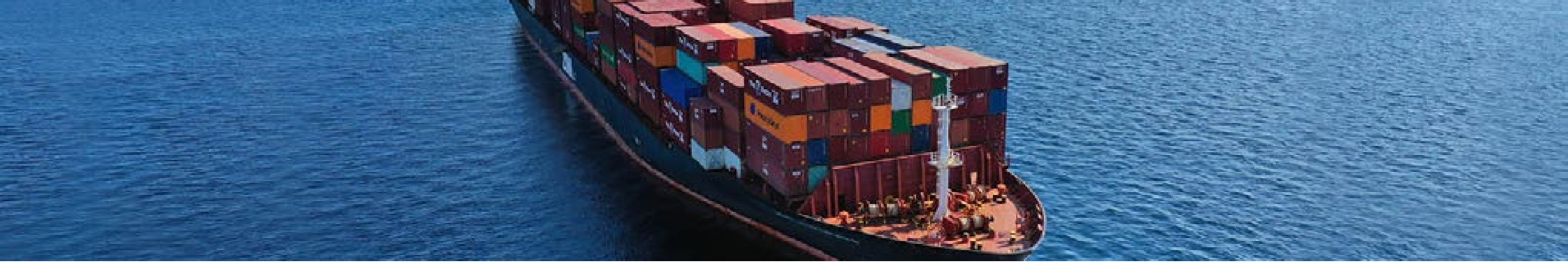
Hydrogen is currently one of the biggest buzzwords in energy transition, as it enables sector coupling and decarbonization beyond electricity generation. **Understanding the Hydrogen Value Chain** explains the different colours of hydrogen, which denote its method of production, and the opportunities offered by the growing hydrogen market.

The supply chain disruption caused by COVID-19 has hit the offshore wind sector hard because of single sourcing. **How Will Renewable Energy Components Recover from the Supply Chain Crisis?** answers some of the most pertinent questions on how companies are coping.

There is enormous potential for solar generation in Southeast Asia. In **What's Ahead for Solar Energy in Southeast Asia**, we look at the situation in Thailand, Vietnam and Singapore along with their different approaches to meeting the growing demand.

In **The Largest Barrier to Hydrogen May Be Transporting It**, we discuss how the biggest challenge in incorporating hydrogen into the energy supply chain is its transportation. Solving this puzzle would hold the key to the global energy transition.

These articles are excerpts from webcasts, roundtables, and teleconferences hosted by GLG Network Members to offer insights into the complex renewable energy market. More events will be organized featuring these experts to help our clients stay ahead of this important development.



LOW-CARBON FUEL ALTERNATIVES IN THE MARITIME INDUSTRY

OLIVIER MACÉ, GLG NETWORK MEMBER AND OWNER AND PRINCIPAL AT BROADMANOR CONSULTING

Marine transportation is an important transportation industry sector, rivaling aviation in size, and it's a significant carbon emitter. Three percent of carbon emissions come from the maritime industry. The ship categories producing most of the emissions are bulk carriers, tankers, and container ships. The industry faces an imperative need for decarbonization. The current trajectory leads to a 20% increase in emissions. While shipping is a carbon-efficient mode of transport, it currently doesn't get a pass and must do its part in reducing man-made emissions.

To be in line with the well-known scenarios of the International Energy Agency, the so-called well-below-two-degrees warming scenario, or 1.5-degree warming, significant decarbonization would be necessary, and it hasn't happened yet.

Maritime Transport Lags in Decarbonization

The marine sector lags behind others — notably road and aviation. There are many reasons, but the main one is that renewing ships and ship engines, which can burn only a certain type of fuel, is a major and costly decision. Ships are on the water for at least 20 years, often more. Owners are eyeing solutions but find it difficult to choose. There is a tendency in the industry for a wait-and-see approach.

The marine sector lags behind others — notably road and aviation.

The trigger for change will be regulations. The cost of fuel is 25% to 40% of the cost of operating a ship. Changing to a different fuel, which might be 50% more expensive, won't happen voluntarily. Shipping is an international business, and you'd expect the International Maritime Organization to take the lead on legislating a framework for decarbonizing marine fuels globally. It is happening, but it's taking a long time.

Meanwhile, Europe proposed the Fuels EU Maritime Initiative in July 2021. It's part of a package of proposals called Fit for 55, designed to reduce emissions by 55%. Between 2030 and 2050, there will be a sea change in the use of energy carriers, away from fossil fuels and toward decarbonization. Different types of fuels, which may have the same energy content, will provide significantly different results in greenhouse gas reductions and carbon intensity. By selecting a carbon intensity target, regulators want to reward fuels and energy carriers that reduce emissions rather than simply reward the renewable fuel content, regardless of greenhouse gas reductions. The trajectory is a 2% reduction by 2025, 6% by 2030, and 75% by 2050.

Another influence is corporations, including Amazon, Ikea, and Unilever, that have pledged to use only zero-carbon fuel by 2050. When you have big corporations making commitments to decarbonize, it has an impact on their whole supply chain, including shipping.

What Makes a Good Marine Fuel?

There are features to what makes a low-carbon marine fuel, and a handful that stand out are:

- Cost
- Energy density
- Sustainability
- Low-carbon intensity
- Safety
- Reliability
- Ease of use
- Compatibility with current fleet and infrastructure

Biofuels and eFuels, synthetic fuels from green hydrogen and captured carbon, make good marine fuels. You have natural gas and biomethane in the form of liquified natural gas (LNG) or bio-LNG, if the methane comes from biogenic feedstock. Feedstock is any biological material used as fuel or converted to a fuel or energy product.

Biomethane/LNG is already proven. Ship owners are converting to LNG or buying new LNG vessels. Biomethane is easy to produce and cheap. It's clean burning and compatible with fossil natural gas. People equipping ships with LNG engines know they'll never run out of fuel. Energy density isn't great, compared with the incumbent marine gasoil and fuel oil. To keep LNG in liquid form, it needs to be cooled to a low temperature, requiring bulky cryogenic equipment. Then there's the cost and time to convert the fleet. Another problem with biomethane is the risk of leakage. Methane is 30 times more potent than carbon dioxide. A small quantity of methane leaked into the atmosphere can have a major impact.

Bio-methanol is already used commercially as a marine fuel. For example, Mærsk has invested a significant amount in methanol ships. One advantage is the number of ways to produce bio-methanol: for example, from biogenic feedstocks, by gasification and reforming the syngas into methanol. You can also produce methanol from green or blue hydrogen with carbon capture. And, of course, there is fossil, or gray, methanol. You'll never run out of fuel, and it's clean burning. Energy density is a drawback, as is cost and time to convert.

Hydrogen and ammonia are grouped together because ammonia converts hydrogen energy into something easier to transport as a liquid. Green hydrogen, from the electrolysis of water with green electricity, could be a long-term solution. It has high sustainability credentials, there's no use of land, it's clean burning, and there's no competition for feedstock. However, hydrogen is a long way from being commercially available. A key problem is the high cost of electrolyzers and green electricity. Converting hydrogen to ammonia improves energy density, but it still doesn't compare favorably with current fossil fuel. Most importantly, handling and safety are an issue: ammonia is highly toxic.

Ultimately, biofuels are the most available and easiest to integrate.

Ultimately, biofuels are the most available and easiest to integrate. Using biofuels delays risky decisions and helps shipping organizations start decarbonization. Both renewable diesel and biodiesel — also called fatty acid methyl ester (FAME) — have been tested extensively to replace fossil marine gasoil, but the price is higher than the incumbent fuel.

Regulators are curbing the use of food crops and pushing the development of waste oils.

In the case of FAME, and renewable diesel using HVO, another drawback is feedstock limitations. The feedstock are lipids: fats and oils. Regulators are curbing the use of food crops, such as palm oil, rapeseed oil, and soybean, and pushing the development of waste oils, such as used cooking oil. However, these are finite resources. Simply put, the world will run out of eligible lipids for biofuels for FAME and HVO.

One way to avoid that is to switch to eFuels, which may be the long-term solution. However, the cost is currently prohibitive, and production capacity is small. But as a long-term marine application, eFuels in the form of fully compatible e-hydrocarbons looking like a diesel or a very clean fuel oil would have an advantage over the simple use of ammonia as a carrier for hydrogen energy.

There are additional possibilities, such as something that would be lower quality than HVO renewable diesel but good enough for marine engines. We might well be describing bio-methanol, but other solutions are coming from some of the thermochemical conversion processes that are being developed to process other feedstocks beyond lipid — such as biomass, municipal solid wastes, recycled carbon, and recycled plastics. What about techniques such as pyrolysis, hydrothermal liquefaction? Could some of the byproducts of these processes be the perfect marine biofuel?

As an example, Mærsk and Vertoro are developing biofuels made from lignin. Lignin is a part of biomass that is difficult to process; in fact, it is the most difficult part from which to get useful products. In other developments, U.K.-based Green Fuels Research recently did a pilot producing a marine biofuel from salmon farming waste. These experiments and others could be a game changer if successful.

This energy industry article was adapted from the GLG Webcast "Low Carbon Fuels in the Maritime Industry."

UNDERSTANDING THE HYDROGEN VALUE CHAIN

DR. KRIS HYDE, GLG NETWORK MEMBER AND DIRECTOR OF HYDEROGEN, DIRECTOR AT HOLLINGWORTH DESIGN LIMITED, A CONSULTANT TO ZEMTECH AND ASSOCIATE TO THE EUROPEAN MARINE ENERGY CENTRE.

The global hydrogen market is experiencing significant change, as green carbon is introduced to a market long dominated by high-carbon hydrogen for industrial applications. Predictions for green hydrogen growth are astronomical. Just how much growth depends on whom you ask. I believe there's not going to be as much growth as others have predicted, but I see >50% CAGR. That rapid growth is expected to occur as customers and shareholders pressure companies to lower their carbon footprints, clean air zones are introduced into cities, and companies consuming large volumes of high-carbon hydrogen consider the possibility of countries decommissioning their natural gas networks.

There are two sources of hydrogen in the hydrogen value chain: high-carbon or low-carbon hydrogen. Currently, ~99.9% of all hydrogen produced annually is high-carbon hydrogen for the industrial sector. It is a well-established market, totaling ~77 million tons a year, using this hydrogen primarily for the refining and ammonia industries. In the medium term, a new market for green hydrogen for transport is developing, and long term there may be other applications, such as the hydrogen gas grid.

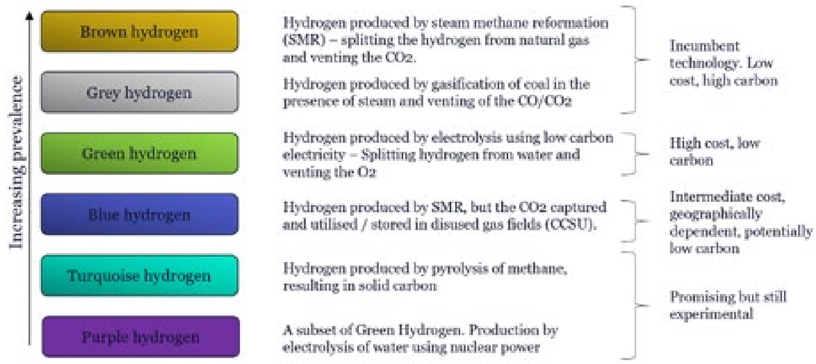
The Colours of Hydrogen

The hydrogen market is split into different colours, based on the method of production. Brown hydrogen is the most prevalent hydrogen globally. Simply put: take the methane from natural gas and put it through a reaction called steam methane reformation (SMR), which splits hydrogen from natural gas. Carbon is released as carbon oxide and vented into the environment.

> Brown hydrogen is the most prevalent hydrogen globally.

Another option is gray hydrogen, made by the gasification of coal. Take coal, heat it in the presence of water, and you get a stream of hydrogen and a separate stream of carbon dioxide and carbon monoxide. It's low cost but carbon intensive.

Green hydrogen is what most people think of as low-carbon hydrogen, and it is produced by electrolysis. Take low-carbon electricity, put it into an electrolyser, and split the water into hydrogen and oxygen. Vent the oxygen and use the hydrogen. The downside is cost, which is roughly two to four times as much as high-carbon hydrogen. It should be noted that the majority of hydrogen cost (70% to 80%) depends on electricity prices; to produce low-cost hydrogen, you need low-cost electricity.



Turquoise and purple hydrogen aren't widely used, but turquoise in particular shows promise for the future; rather than releasing carbon as carbon dioxide, it forms solid carbon powder. In theory, you can capture that powder and bury it or convert it in another process. Because it's a solid, it doesn't directly enter the atmosphere.

Purple hydrogen is a subset of green. With purple, you're splitting off hydrogen from water, but electricity comes from nuclear power rather than a renewable source, such as wind.

Blue hydrogen is interesting. It's seen by many governments as the answer to lowering their carbon emissions at a low cost. It's essentially the same as brown hydrogen, but rather than venting the carbon dioxide, it's captured and used in an industrial process or pumped underground and stored in disused gas fields. Considering costs, you're taking SMR hydrogen (at about $2/kg) and adding another process (about $1.50/kg), so it's going to be more expensive than brown or gray hydrogen, but cheaper than green, which for most applications starts at ~$6/kg. The problem is it's geographically dependent. Not every country can do this, because disused gas fields aren't widely available. For those countries where it is an option, there has been a significant amount of government funding and economic investment. Blue hydrogen is popular with oil and gas companies because it fits their business model as they can still keep producing natural gas.

Worldwide, there are a handful of blue hydrogen projects operating at scale.

Worldwide, there are a handful of blue hydrogen projects operating at scale, but there are continuing questions about methane leaks and whether carbon dioxide remains sequestered. There's no doubt blue hydrogen will be a major part of future energy processes, but there are many unknowns.

A Look at Green Hydrogen

Green hydrogen is my background. The process is simple. You start with renewable energy and power an electrolyser, which splits water into hydrogen and oxygen. You often then feed the hydrogen into low-pressure storage, and then into a compressor, because most applications for hydrogen require greater pressure than electrolysers can produce.

There are several electrolyser technologies.

- Liquid alkaline technology, the lowest cost, was commercialized around the 1930s and used at massive scale in the '50s and '60s. It has a large footprint and doesn't respond quickly to changing power from, say, a solar panel. However, most industrial applications require an input of hundreds of MW, and at this scale renewable power sources change slow enough for the alkaline electrolysers to be an option.
- PEM technology was developed for military and space applications and has been commercialized over the last decade. It has a smaller footprint and responds quickly to changing power, but it's costly and difficult to scale.

- Solid oxide electrolysis is still at the prototype stage. Its strength is its high efficiency, a consequence of running at high temperatures. But it's costly and uses expensive, rare materials. Significant scale-up is required, but in 10 to 15 years, solid oxide technology may be used for industrial applications or centralized production.
- Alkaline exchange membrane electrolysis has been in development the last few years and has some potential. It's not at a commercial scale yet, but it may be so in another 10 years.

People often ask which technology is "the best," but each has strengths and weaknesses, leading them to be more suited to different applications and customers.

Electrolyser Manufacturers
Investment in these companies is significant and share prices have skyrocketed. The top-tier companies are split between big multinationals and smaller pure-play hydrogen.

What differentiates top-tier companies is the quality of their partnerships and how many different electrolyser technologies they offer. If a company marketed PEM, alkaline, and solid oxide (which presently none of them are), they could sell the best technology for a customer's application rather than shoehorning one technology into every customer's requirements.

Partnerships, particularly with EPCs, are crucial. Each of the top-tier companies has partnered with an EPC: Linde Engineering is partnering with ITM Power; Nel has partnered with Wood; and Siemens has an in-house EPC, as do Thyssenkrupp and Cummins.

In summary, the markets for hydrogen are growing rapidly, and there are many opportunities for to enter these markets, either directly or as a supplier or subcontractor.

This energy industry article was adapted from the GLG Webcast "Understanding Hydrogen Value Chain."

HOW WILL RENEWABLE ENERGY COMPONENTS RECOVER FROM THE SUPPLY CHAIN CRISIS?

RICHARD TURNER, GLG NETWORK MEMBER AND FORMER JDR CABLES GROUP CHIEF EXECUTIVE OFFICER

Prior to COVID-19, offshore wind was expected to compete with fossil-fuel-generated energy and significantly impact the energy transition. However, due to the current supply chain component shortage, the likes of Vestas and SGRE have more than 30 gigawatts of new global capacity at risk.

There are numerous challenges, but many companies are dealing with them remarkably well, according to Richard Turner, the former Chief Executive Officer at JDR Cables Group.

"One thing that's consistent with everyone who operates in the space is that the pandemic fully tested their business continuity plans, and in many areas, it sort of exposed some weakness in them, and in particular, with procurement strategies."

Sam Stopps, GLG's Manager of Client Solutions and Public Equities, spoke with Turner via a November 17, 2021, teleconference, and the following is an excerpt from that broader conversation.

Can you discuss how COVID-19 has impacted renewable energy supply chains and the current crisis in supply chains?

For the last 10 years or so, offshore wind developers have been working collaboratively within the supply chain because there has been such a drive for cost reduction. But this single sourcing — or sourcing among a handful of suppliers — has caused issues whereby that business may have been particularly affected by the pandemic without a plan B. Also, there were issues in installation stages with the timing of componentry arrivals.

There were different places with different lockdown policies at different times on a global basis. But the majority of companies were able to continue because they were deemed as essential workers, and therefore, able to weather the storm reasonably well on the whole.

During the pandemic, the biggest issue was logistical.

During the pandemic, the biggest issue was logistical. With the global shortage of drivers, shipping containers, and other resources, there was a pent-up demand exacerbated even further by a surplus of demand in the market. This really hampered offshore companies for new construction projects and operations and management (O&M) activities in existing wind farms. Now that restrictions have eased, there's a scarcity of skills because everything's drawn from the same resource pool.

Can you specifically discuss the shortages of wires and cables for offshore wind and potentially comment on how some of the major producers are positioned in this space?

If you segment the market by medium and high voltage, there is no linear relationship between the demand for medium voltage and the number of gigawatts of offshore wind that's deployed because the turbine is getting bigger. Effectively, if your turbine is twice as big, then you have half as many of them per gigawatt of installed capacity. Therefore, you technically need less array cable per GW.

That (MV) market is growing due to the increase in global volume, but it's not growing anywhere near as quickly as the high voltage (HV) sector because all of the wind farms need export cables. That growth is further enhanced by the fact that wind farms are moving farther from shore and need more kilometers of cable along with changes in technology. Specifically, above a hundred kilometers, you go from HVAC to HVDC cable, which is required for efficiency, so there's a shift in the market to HVDC. This puts it in competition with the interconnector cable market, which uses the same HVDC cables where you literally connect countries, or parts of countries, together with a massive, high-voltage cable.

The growth in the HV and the HVDC market is really quite significant, and the market capacity hasn't increased that much in recent years. There have been some investment decisions, but not enough capacity has been added to really deal with what is going to be a scarcity of supply. All of the cable manufacturers will be extremely busy manufacturing for subsea, HVAC, and HVDC projects, and the majority of the facilities that the cable companies have are also producing power cable and HV cable for land applications.

The grids in most countries need upgrades.

There is this perfect storm of demand whereby you've got massive offshore cable demand growth caused by mass deployment of wind farms and more widespread use of interconnected cables. Plus, the grids in most countries need upgrades, and there is a lot of work ongoing with electrification of railways. This means a lot more power cables are needed, and they are harder to get within a reasonable lead time.

Also, there have been a vast amount of insurance claims relative to cable failures. This is not just because cable manufacturers don't make the cables correctly. It's because they get cab damaged during installation, and once they're installed, they can be damaged by trawlers, ships, anchors, and more.

There is a lot of intervention and repair work along with new cables being added to existing wind farms, so that's just another layer of demand into these cable facilities. The world needs cable and will continue to need more as far ahead as I can see.

Can you discuss the impact these shortages have had on offshore wind project delays and how some of the world's existing players are coping?

There have been delays due to the reasons I mentioned previously, but wind farm projects have a long gestation period of more than 10 years. So the time frame of the pandemic isn't (yet) that much in the grand scheme of the overall development of wind farms. There has been a short-term impact caused by scarcity of componentry where COVID has been a factor, but the majority of developers have adapted very well to get things delivered.

They are more worried about the availability of materials, the possibility for lockdowns, getting stuff moved around, mobilizing people in the execution phase of the project, and the technical issues that have a large financial impact on them. Overall, they're in an industry that is growing incredibly rapidly, so the future pipeline and outlook for all of the developers, suppliers, and offshore wind is incredibly bright.

Can you discuss the current inventory supply of critical wind components, what the current inventory stocks look like, and if there are any specific components that you think will be shorter than others?

The vast majority of components for wind are engineered and manufactured to order with a 15-plus-year design life, so a lot of what's available, and the cutting-edge technology available to these developers, changes dramatically throughout that period. There's not much new stock sitting around in the industry at all, but what is emerging is in the O&M side where wind farms 10-plus years old need to be repaired, replaced, overhauled, repowered, etc. A turbine can be brought onshore, refurbished, put into stock, and then put back in the supply chain and sold when one fails.

A strong area of the market that's emerging is how to repair, overhaul, maintain, upgrade, and remanufacture componentry, and then use it again like a recycling project. That's where I think there may have to be a level of inventory in the future, along with things like spare blades, etc., in case there is storm damage.

With the current crisis in supplies and project delays, do you believe this could lead to an increase in price for renewable energy, specifically offshore wind, or that the price won't be impacted by this?

The price of components, raw material, and pretty much everything shot up of late.

The price of components, raw material, and pretty much everything shot up of late, and that cost needs to go somewhere. Many developers have already won contracts for differences (CFDs) at a strike price, and the cost of materials is what the price is (unless they've managed to hedge or lock in prices with the supply chain), and they'll have to absorb it themselves. That could translate into a higher cost on the project and affect their return.

Ultimately, I don't see the strike price in auctions going up significantly. However, I don't expect it to go down as quickly as it has... It couldn't possibly go down at the rate that it has in recent years.

I expect through innovation and economies of scale, the cost of floating wind will come down from where it is because it's at the "demonstrator" stage, and there's still quite a way for it to go. I expect that will maintain a decent trajectory in terms of cost reduction. But, in terms of fixed offshore wind, I think the price will stay relatively flat. Hopefully, the price of componentry and raw materials will start to come down to a more manageable level as the world and the economies of the different countries, in particular in Europe, start to recover.

Do the current labor shortages impact the supply of renewable energy components?

It has because the labor market for skilled employees in Europe is fairly buoyant. Post-Brexit, it has been more difficult to recruit people from abroad, so that's had an impact. But I would say the biggest area where I have concern, in terms of our ability to deploy large volumes of gigawatts in the next 10 years, is the offshore skillset. There will be a need for people who are competent and qualified to go offshore and operate safely in a sort of customer-facing environment to do the technical aspects of installation.

This renewable energy industry article is adapted from the GLG teleconference "Renewable Energy Components Crisis."

WHAT'S AHEAD FOR SOLAR ENERGY IN SOUTHEAST ASIA

CHRISTOPHE INGLIN, GLG NETWORK MEMBER AND MANAGING DIRECTOR OF ENERGETIX PTE LTD.

The growth of solar electrical generation in the developed world — Europe, the U.S., Japan, and, to an extent, Australia — has been phenomenal. But in less-developed nations, and particularly Southeast Asia where electrical grids are not as mature and there is enormous unmet demand, solar growth potential is even greater.

For many years, solar generation was simply too expensive.

For many years, solar generation was simply too expensive. Subsidies helped the industry gain traction, and around 2010 there came a tipping point. Power prices were relatively high, and economies of scale kept driving down the cost of renewable energy, helped by improvements in technology. Today, the cost of photovoltaic (PV) generation makes it not only competitive but also compelling.

Let's look at the opportunities in Thailand, Vietnam, and Singapore, which have different approaches to meeting the growing demand for electricity.

Solar Energy in Thailand

Thailand is easily the longest-established Southeast Asian market for electricity generated by photovoltaic (PV) modules, with its involvement in solar going back to the 1990s. In the beginning, the government provided a level of subsidy and made licenses available very easily, but there weren't many takers because the returns were so low. Eventually the Solar Power Group Company saw an opportunity and started acquiring licenses to develop projects. As the price of PV panels plummeted, solar farm projects became very attractive, generating internal rates of return of 30%, 40%, and 50% before the government curbed the incentives. It was quite crazy.

Today, the solar-farm phase is over, generation has moved to rooftops, and pricing is more market driven. Developers are finding a big market because there are lots of very large rooftops on industrial sites. It's very attractive for a developer to build a rooftop project on behalf of a building owner and sign a power purchase agreement (PPA) to sell them electricity at a discount. These discounts are somewhere in the range of 30% compared with the peak tariff.

Thailand has been a great example of how policymakers can be very proactive in promoting solar. They are a stable group, they involve industry, have lots of discussion and interaction, and, luckily, seem to be insulated from politics.

Solar Energy in Vietnam

In contrast to Thailand, Vietnam is a much newer market for solar. Fueled by population growth, demand for electricity in Vietnam has been growing at a compound annual growth rate of 9.7% since 2010. The nation's standard of living is rising, requiring a lot more electricity per person.

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Based on the German model, Vietnam came out with a feed-in tariff set originally at 9.53 U.S. cents per kilowatt-hour for 20 years. International bankers and analysts considered the contracts unbankable at first, seeing a lack of acceptable guarantees from the state monopoly EVN as counterparty, but local entrepreneurs weren't worried about the utility reneging, and entered the market. The feed-in tariff dropped to 8.38 cents after the end of last year, and there's now talk of a much bigger drop to under six cents.

Inevitably, Vietnam will switch to market-based prices, much the way India did years ago, the way Singapore has always operated, and the direction Thailand is headed today.

Solar Energy in Singapore

In Singapore, the government has always avoided market-distorting subsidies. The nation-state's Energy Market Authority, the key regulator, has consistently welcomed all forms of regulation-compliant generation, but never offered feed-in tariffs. Yes, there were initially some small grants and some payments for test-bed purposes, but there were never any subsidies in the actual market.

Because of its size, Singapore doesn't have much land for solar farms, and private landed housing comprises only about 2% of the market. Industrial and commercial rooftops in the private sector have been key to driving the market, as has the Housing Development Board (HDB), which has installed solar panels on thousands of apartment buildings.

Since rooftop projects are much smaller than utility-scale solar farms, the problem in Singapore was reaching economies of scale to make borrowing money easier. To solve the problem, the Economic Development Board of Singapore got together with the HDB and JTC, the government agency in charge of industrial development, to bundle rooftop packages of 50 to 70 megawatts, which are big enough to attract financial investment and bring down costs through economies of scale.

Recently, as Singapore became more interested in meeting its carbon goals and commitments to the Paris Agreements, it has set some ambitious solar targets. Specifically, it intends to reach 1.5 gigawatts of PV capacity by the year 2025 and 2 GW by 2030. As of the first quarter of this year, nearly 450 megawatts are installed, leaving around 300 to 400 megawatts a year to reach the 2025 target.

This energy industry article is adapted from the GLG Remote Roundtable "Navigating the Solar Energy EPC and Developers Landscape in SEA."

THE LARGEST BARRIER TO HYDROGEN MAY BE TRANSPORTING IT

MANFRED WAIDHAS, FORMER CHIEF TECHNOLOGY OFFICER AND HEAD OF TECHNOLOGY AND INNOVATION AT SIEMENS HYDROGEN SOLUTIONS

Hydrogen, a feedstock for many industrial processes, will enable the green energy transition due to its capability for "sector coupling." But while hydrogen supplies may be plentiful, much of the challenges in incorporating this more sustainable fuel into the world's supply will be in transporting it.

The different colors of hydrogen.....:		*... and their relevance:*
colorless:	Wikipedia believes so	
grey:	via natural gas	fossil route is most economic but linked with CO2 emissions
black:	via coal	dito, coal even cheaper than natural gas
blue:	via coal/coke with subsequent CO_2 sequestration	dito, but with subsequent CCS* (sequestration of CO2)
turquoise:	via natural gas pyrolysis	solid carbon instead of CO2 as waste
red:	water splitting via nuclear electricity	no CO_2 emissions; but nuclear waste; **sector coupling viable**
green:	via renewable electricity	**no CO_2 emissions or waste; sector coupling viable**

* carbon capture and storage

In specific regions of the world, costs of hydrogen will be close to $2 per kilogram within the next few years. That doesn't include transportation costs, which can add another dollar per kilogram of hydrogen. In Europe, it will be slightly higher, but we also have to consider the concept of energy independence.

Roughly 70% of the cost to produce affordable green hydrogen comes from electricity prices. For example, sun yields in the Gulf region or western Australia are better than in northern Europe. There are good wind conditions at north or south shorelines such as Patagonia. But in most cases, the coupled industry is far away. We have to consider how to transport an ultralight molecule to where it will be utilized.

On the road, it's relatively easy. Hydrogen can be delivered in a compressed gas form, but only 500 kilograms can be transported in a 40-ton truck. This is a hazardous material, after all.
In large land masses such as Europe, green and blue hydrogen can be transported through pipelines, delivering roughly 10 times more power than an electrical line can deliver. It's always better to transport molecules, essentially hydrogen, than electricity. The advantage of a pipeline is simple: you have high up-front capital expenses, but the operating expenses are low. There are plans to repurpose existing natural gas grids step by step for the use of hydrogen. In Germany, for example, there's an existing hydrogen pipeline grid of roughly 1,000 kilometers connecting chemical industries.

Of course, pipelines are restricted to a mainland — connecting Australia to Europe is out of scope for any pipeline. Let's consider Japan, an isolated location where 94% of the energy is imported via the sea. The country is currently thinking about how to import green and blue hydrogen. It can be delivered in pure form, meaning you have to cool it down to minus 253 degrees C to liquefy it for transport. But with this procedure, you lose one-third of the energy. Other concepts are under discussion. One of them is to transport using ammonia, at minus 60 degrees, so it liquefies even earlier and hence is easier to transport. This way can use existing transport vessels. A third method is liquid organic hydrogen carrier.

These three concepts — pipelines, cooled hydrogen via sea, and LOHC — are currently competing, and it's still an open race.

> There also exist concepts to blend hydrogen with natural gas.

There also exist concepts to blend hydrogen with natural gas. As a rough rule, the production of green or gray hydrogen after production using natural gas is roughly $2 per kilogram at the start. That means if you add mixed hydrogen to the natural gas grid, you degrade the value of hydrogen to its heating value only, ending up at $1 per kilogram. If you can keep it in its pure state and use it as a feedstock, it'll stay in the range of around $2 per kilogram.

Hurdles always existed for hydrogen, but what's changed now are the incentives to incorporate hydrogen into the energy supply. The first hype wave around hydrogen, in the 1990s, was concentrated on automotive propulsion and local emissions. What is different now is the commitment of many countries to reduce their CO2 footprint, and hydrogen is a good solution until we fully transition to renewables.

This energy industry article is adapted from the GLG webcast "Hydrogen — Latest Trends and Challenges."

ABOUT OUR EXPERTS

OLIVIER MACÉ

Olivier Macé is owner and Principal at Broadmanor Consulting, a biofuels consultancy. Previously, he worked in the downstream oil and biofuels sectors for 31 years, holding various roles in refining, trading, supply and logistics, fuels, and lubricants sales, as well as renewable energy. Olivier joined BP Biofuels at its inception and held various leadership positions, including Regional Director, Europe and Africa and Global Head of Strategy, Regulatory Affairs and Communication. Olivier was Biofuels Director, Europe Fuels at BP, responsible for the biofuel's commercial performance in the entire region.

DR. KRIS HYDE

Dr. Kris Hyde is a leading U.K. authority on hydrogen technologies and the hydrogen market and has 18 years of experience in this space. He was recently a senior manager at ITM Power Plc, where he worked in the key teams of Science, Engineering, and Commercial, giving him a broad understanding of hydrogen technologies. He is currently a director of consulting firm HYDErogen, Director at Hollingworth Design Limited, and a consultant to the European Marine Energy Centre (EMEC) Ltd. and ZEMtech.

RICHARD TURNER

Richard Turner is Chief Executive Officer of Bel Valves and Bel Engineering. Before this, he was the JDR Cables Group Chief Executive Officer and Chief Operating Officer. Prior to this, Richard was the Technip Umbilical Systems Vice President of Global Manufacturing. Richard is a leading executive on the market for subsea cables and offshore wind.

CHRISTOPHE INGLIN

Christophe Inglin is the Managing Director of Energetix Pte Ltd., which he co-founded in August 2015 with two colleagues from Phoenix Solar. From December 2006 until July 2015, Christophe was Managing Director of Phoenix Solar Pte Ltd., which he co-founded in late 2006 as a joint venture with local partners and the German company Phoenix Solar AG. Prior to that he was the Managing Director of Shell Solar. Mr. Inglin is also Vice Chairman of the Sustainable Energy Association of Singapore (SEAS), where he also chairs the Renewable Energy Committee.

MANFRED WAIDHAS

Manfred Waidhas is an independent consultant in the energy industry, advising on the hydrogen technologies, power-to-X, and energy storage space. Previously, Manfred was Chief Technology Officer and Head of Technology & Innovation in Siemens' Hydrogen Solutions Division (2015-2019). Before this, Manfred was Chief Executive Officer of Siemens' Hydrogen Solutions (2015-2015) and Program Manager of Energy Storage at Siemens (2005-2010).

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