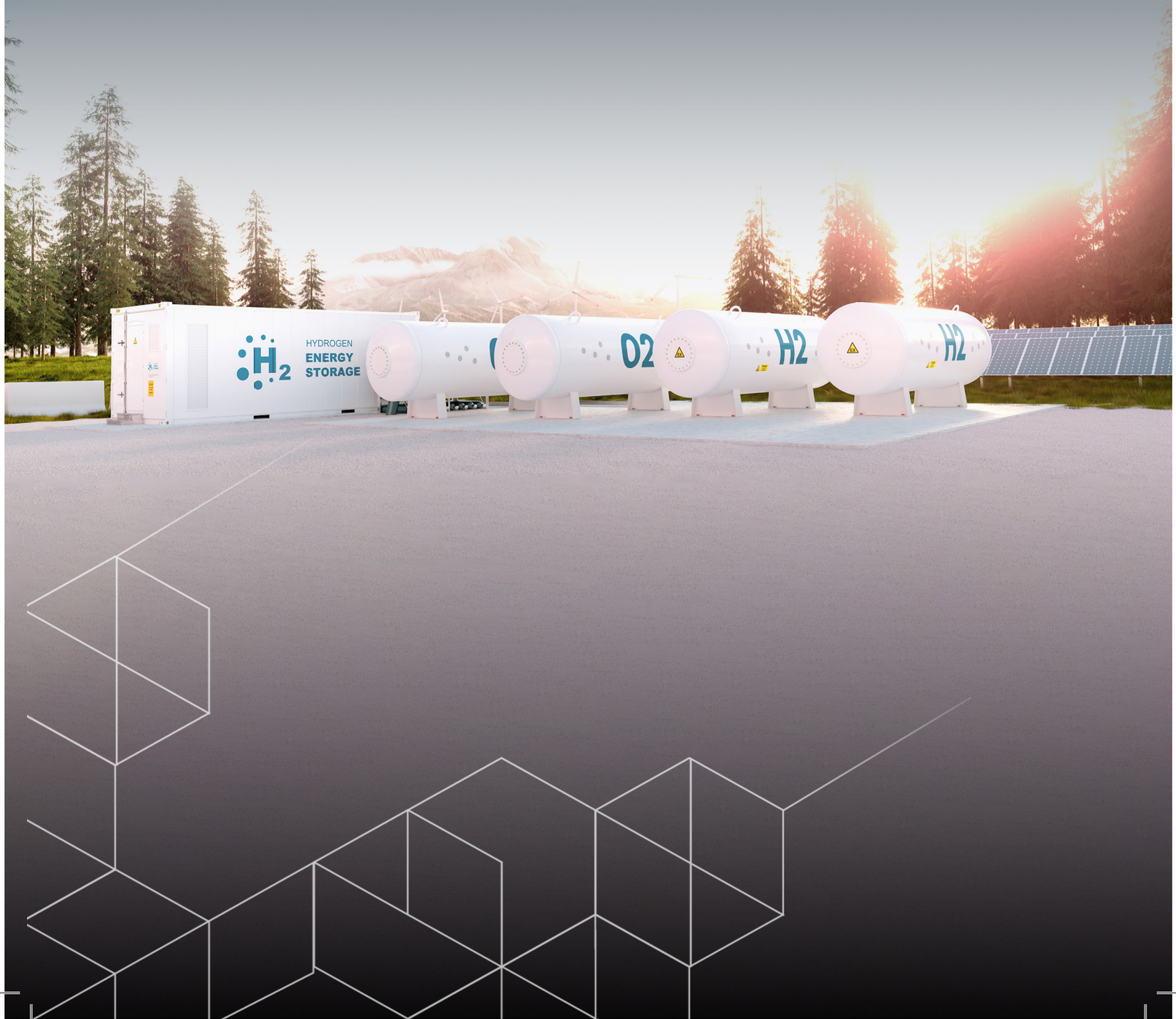
quorum software

Energy Accounting Software for the Hydrogen Economy



Executive Summary

For more than three decades, Energy Components by Quorum Software (EC) has been the industry's flagship solution for production reporting, allocation, and hydrocarbon accounting in the energy industry. Used by all supermajors as an industry-standard solution. One of the key strengths of EC is the agnostic approach to business processes in the energy value chain, which allows handling a broad range of energy carriers, raw materials, and byproducts.

The energy accounting and business processes around hydrogen, covering production, transport, storage, sales, revenue, and commercial management are very similar to those in the LNG and conventional natural gas sectors. EC currently processes 50% of all LNG export and import globally. Through this whitepaper, we explore and discuss how EC can support energy business operators in a future global hydrogen economy.

Hydrogen is considered one of the most promising energy carriers in helping the world to net-zero carbon emissions in 2050. In the near future, hydrogen will be used to supply energy to hard-to-electrify sectors, long-haul transport, and provide seasonal storage and balancing mechanisms for renewable electricity.

During the production of hydrogen, it is important to measure not only the hydrogen produced but also all other byproducts and allocate these back to all input energy and raw materials used. As hydrogen is produced, transported, and stored in multiple ways this can result in greenhouse gas (GHG) emissions, either direct or indirect. These need to be accounted for transparently in order to meet regulatory requirements or provide certificates to guarantee the origin of the hydrogen. EC Environmental contains the functionality required to do this.

To optimize the hydrogen production process, meet regulatory requirements, and operate the production facility as efficiently as possible, strong plant management software such as EC is required. EC provides integrations with data historians, a highly configurable calculation engine for mass balancing, forecasting functionality, and specific modules for maintenance planning, laboratory data, sample management, chemicals, and data on product quality.

EC provides functionality to support inventory management, all terminal operations, transport optimization, planning, and forecasting, pipeline operations, storage operations, and all other processes required to run and improve the operation of a hydrogen storage or transport facility for hydrogen in a gaseous state, as liquid hydrogen or in the form of ammonia.

EC is an end-to-end solution that also includes sales and revenue functionality. Capable of handling all contracts, price calculations, indices, and other processes for hydrogen sales and revenue recognition. Other functionalities include a customer portal, data and analytics tools and mobile apps. With EC as-a-Service (ECaaS) and hydrogen-specific product configuration in Energy Components can be delivered at a price point suitable for lower margin energy businesses such as renewable fuels.

Contents

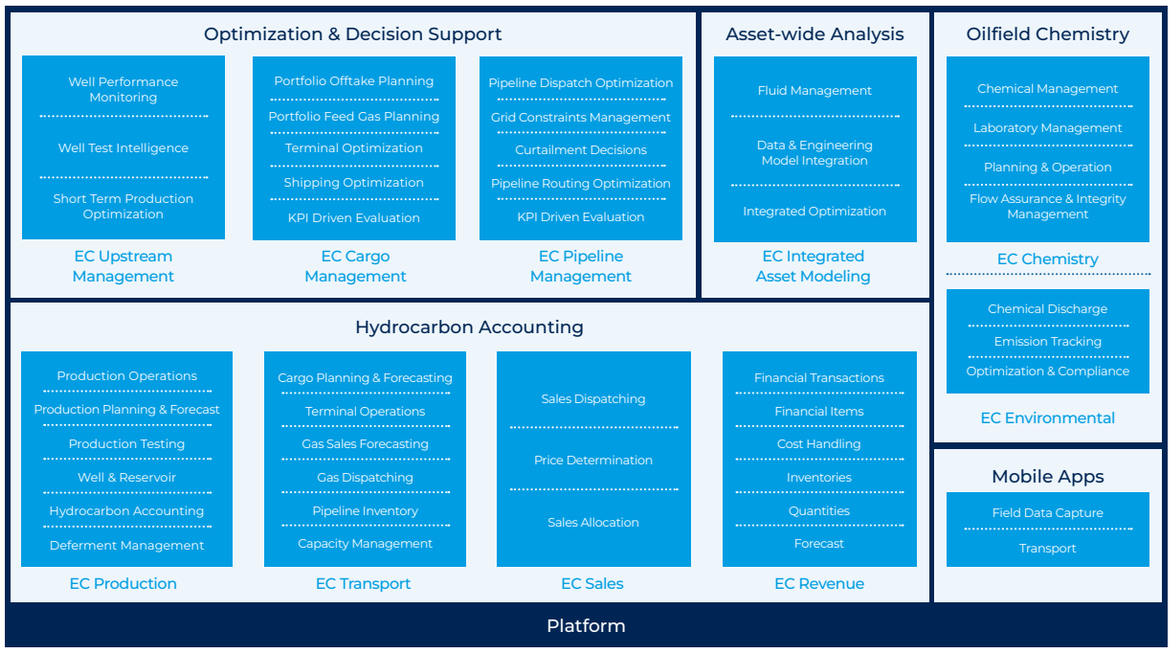
Energy Components

Our History

For more than three decades, Energy Components by Quorum Software (EC) has been the industry's flagship solution for production reporting, allocation, and hydrocarbon accounting. With 650 licenses installed in 55 countries, EC manages a significant portion of the world's production of hydrocarbons, making it the global industry leader (IDC MarketScape). Today, more than 100 energy companies, including all oil and gas supermajors, use EC as an industry-standard solution for their operations.

Accumulating a wealth of experience over the years, EC has evolved as more knowledge was accumulated and new functional areas were added to the product suite. This is a natural consequence of our ambitious product strategy and close partnerships with our customers. From delivering regional production-based solutions in the North Sea to providing complete upstream and midstream business solutions globally, EC has developed into an end-to-end management solution for liquid and gaseous energy carriers.

The EC product suite offers unprecedented support for the whole value chain, with dedicated support for production operations, terminals, pipelines, liquefaction facilities, regasification facilities, and more. Our strategy is to offer one integrated solution for the global energy industry. The portfolio currently consists of the following fully integrated solutions that share the same underlying database and platform.



Our Future

The Energy Transition is transforming the entire world, and as a strategic partner to the energy industry our strategy is to assist new and existing customers in this transition.

One of the key strengths of EC is the agnostic approach to business processes in the energy value chain, which allows handling a broad range of energy carriers, raw materials and by-products through configuration rather than implementing individual bespoke solutions.

All energy business operators, be it within hydrocarbons or renewables, need to keep records of raw materials and process inputs, the amounts produced, consumed, re-injected, or disposed of, and the delivery, transport and sales of products to buyers and other facilities. For each area, a full cycle from forecasting to accounting can be handled, allowing performance to be tracked against forecasts and targets at all levels. EC strengthens energy businesses by offering fully integrated functionality that supports energy production accounting, optimization, and forecasting.

Quorum Software expects that as the hydrogen economy matures, it will follow a similar path to the LNG economy when it comes to dynamically changing contractual and pricing agreements, using a combination of interlinked large-scale and small-scale distribution networks, the introduction of regulations related to third-party access (TPA) and bunkering facilities, and continuous development of new commercial services. Quorum Software has more than 15 years of experience within LNG and midstream operations collaborating globally with all the major players, and our consultants have obtained in-depth experience and knowledge regarding all aspects of this economy. Quorum has developed models and approaches based on best practices and has supported our clients achieve a competitive edge. This encompasses the domains of product marketing, cargo management, export and import operations through sales and revenue.

The Market Leader of LNG

Today, LNG acts as a global balancing energy through the growing network of LNG terminal and regasification infrastructure and is touted as the “transition” fuel for the shift from coal to gas. EC is the market leader within LNG and over 50% of all produced LNG is managed by EC. However, as the Energy Transition picks up speed, we believe that hydrogen will gradually take over this role, since dependency on batteries at a global scale arguably could have severe sustainability issues related to mining and extraction of raw materials. We see many similarities between the business processes of the LNG economy and a future global hydrogen economy and we will explore and discuss how EC can support this future global hydrogen economy.

The Hydrogen Economy

Where once hydrogen was primarily used as rocket fuel and until recently used in oil refining and ammonia production. It is now considered one of the most promising energy carriers in the energy transition helping the world to net zero carbon emissions by 2050. Recent developments in technology and finance have resulted in a promising large-scale hydrogen economy.

Hydrogen is a potential game changing energy carrier for industry, the consumer market, and as a balancing fuel for the renewable electricity system.

Industrial usage is expected to grow in hard-to-electrify industrial sectors such as cement, steel, long-haul transport, etc. Currently, these heavily rely on conventional hydrocarbons as their source of energy. In the Netherlands, the hydrogen consortium NorthH_2 partnered with the industrial hydrogen user OCI to create the first integrated green ammonia- and methanol value chain in their Dutch plants.[1] Currently these large industrial users of hydrogen are creating the economic climate for hydrogen producers to invest in larger hydrogen plants, as the demand for hydrogen is secured.

In the transportation sector, hydrogen will play a large role as well. The network of hydrogen fueling stations for the transport sector is increasing. This will make fuel cell vehicles an alternative for battery-electrical vehicles, especially in long-haul transport and public transport, limiting the environmental impact of batteries. For the shipping sector, hydrogen is expected to compete with LNG as a fuel to replace conventional fuel oil. The commercial cruise industry has shown that using a fuel that doesn't produce any particles or smell makes a positive impact on tourists during their holidays.

Hydrogen may also be a potential replacement for natural gas in domestic and industrial usage for heating. In the United Kingdom, grid[2] operators National Grid and Scottish Gas[3] Network blended up to 20%[4] of hydrogen with the natural gas in their grids being delivered, to both industrial users and domestic consumers. No differences in terms of the performance of gas-fired appliances were reported during these trials. The ambition is to gradually increase the renewable hydrogen content to 100%.

Another role of hydrogen is to address the intermittency challenges of utility-scale wind and solar energy. Since hydrogen electrolysis plants can quickly increase their hydrogen production, when there is an excess in renewable electricity, this electricity can be converted into green hydrogen and stored. The hydrogen can later be converted back to electricity when there is a shortage in electricity production.

Renewable hydrogen is currently receiving strong support from governments and businesses around the world, with the number of incentives and projects expanding rapidly. Furthermore, current research projects indicate these investments are likely to become economically feasible in the coming years.[6] As a result, it is expected that in the next decade, the first large- scale hydrogen production facilities will come into operation, and hydrogen will take its place in the renewable energy economy.

Hydrogen Value Chain

Industrial-scale hydrogen production is accomplished in multiple ways as shown in Figure 1, and can be renewable or non-renewable. Currently, hydrogen is produced primarily from natural gas via the Steam Methane Reforming process (SMR). This process produces carbon dioxide along with hydrogen, hence this method is not renewable on its own. It is possible to implement Carbon Capture and Storage (CCS) procedures to reduce the environmental impact of SMR hydrogen production. This is also possible for hydrogen creation from coal, using Coal Gasification and Water-Gas Shift. Other fossil fuels such as wet and dry biomass can also be used to produce hydrogen and are classified as renewable. Considering the energy transition, hydrogen production via electrolysis, is preferable, where demineralized water is converted into hydrogen and oxygen. The electricity to run the electrolysis process can come from different sources, such as renewable solar, wind, and hydro, or others such as nuclear, biomass, and of course conventional power plants. The carbon intensity of the hydrogen will depend on the electricity mix used, and whether abatement procedures, such as CCS are implemented.

Apart from hydrogen, most processes will have other outputs and reactants as well such as oxygen, nitrogen, steam, heat or chemicals and catalysts. These outputs and reactants are not depicted in the figure below, but can in some cases also be marketed commercially, or require measurement, tracking, and reporting for regulatory compliance.

Eventually, the hydrogen produced will have to be stored or transported to its consumers. This could be done in multiple ways, many of which are similar to how we handle natural gas. The preferred method for large-scale transport will be via dedicated hydrogen pipelines or existing natural gas pipelines in which hydrogen is added to the natural gas. Ground transportation or by marine vessels will also be possible and comparable to LNG.

Hydrogen can also be stored in facilities that are similar to natural gas, such as empty salt caverns.[7] When the hydrogen is mixed with natural gas, existing storage facilities also become options for storage. Another option is storing the hydrogen in the form of ammonia[8] as this is stored in a liquid form and has a very high energy density which can easily be converted back to hydrogen, or used directly in fuel cells, without producing CO_2 or SO_x emission.

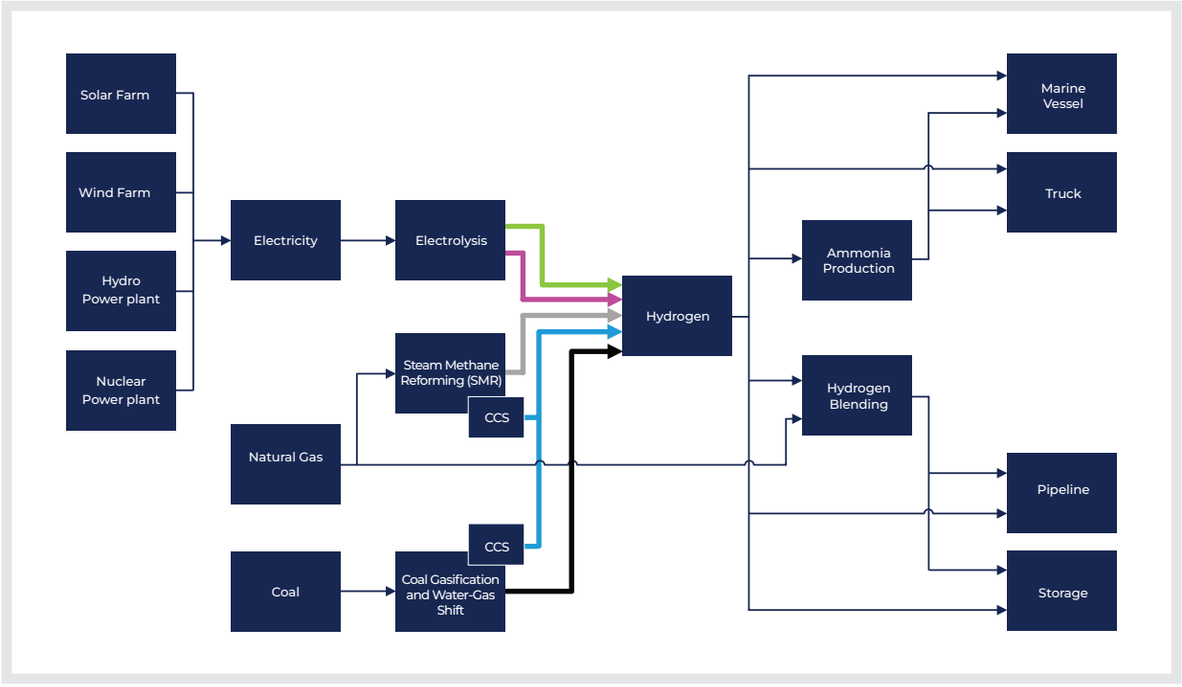


Figure 1 Hydrogen value chain

At all stages of the hydrogen value chain, there is the need for information systems to support the complex business processes unique to this energy sector.

Use Case	Solution Capabilities
Physical and commercial plant management	Manages both the physical processes in the plant, tracking, allocating and reporting on gasses, liquids, equipment statuses, laboratory and environmental data and transport in one tool, while continuously combining this with the commercial aspects of sales, revenue, and ownership.

Use Case	Solution Capabilities
Manage the complete Hydrogen portfolio	Used for all sizes of operation: from a single hydrogen facility to the complete portfolio of a company. Managing multiple large-scale electrolyzers, storage facilities, transport, sales, and revenue for an organization from a single instance.
Proven technology	EC is the market leader for hydrocarbon accounting and management in the upstream and midstream energy industry. Over 50% of the LNG import and export terminals around the world use Energy Components. Although LNG and hydrogen seem very different, their business processes and IT system requirements have shown strikingly close resemblance.

The Colors of Hydrogen and Carbon Intensity

As described earlier in this chapter, hydrogen can have different manufacturing processes and feedstock. It has become a common practice to assign a color to fuels to indicate how renewable the fuel is. Hydrogen is not different in this practice and is commonly assigned a color. Green, blue, and grey hydrogen[9] are the most common color labels:

- Green hydrogen produced from a surplus of renewable energy. In most cases this will be via electrolysis using 100% renewable electricity from wind, solar or hydro. In some cases, hydrogen from solar power is marketed as yellow hydrogen.
- Grey hydrogen is produced from fossil fuels, most commonly from natural gas via steam methane reforming. This also produces CO_2. It currently is the most widely used method for hydrogen production, accounting for 95% of the current global production.
- Blue hydrogen is like grey hydrogen but is combined with Carbon Capture and Storage (CSS) processes.

Other less used color labels are:

- Pink hydrogen, which is produced from nuclear power.
- Brown or black hydrogen produced from lignite or black coal and can be combined with CCS.
- Turquoise hydrogen is produced from methane via pyrolysis. This produces hydrogen and solid carbon, which is not yet used at scale.
- White hydrogen, which is naturally occurring hydrogen in underground deposits and produced through fracking. There are currently no strategies to exploit this.

As the color terminology of hydrogen represents its carbon footprint from energy consumption, accurate accounting of the energy mix used in its production, transportation, and storage is important when traded in an open market. As with other renewable fuels like renewable electricity and biofuel, transparent processes that are traceable and accountable from source to the point of sale, are required. The possibility to calculate and track the carbon footprint of hydrogen is especially important during the transition to renewable hydrogen since grey hydrogen is still the most produced of all types.

Hydrogen measuring, monitoring, and emissions reporting are required to meet regulatory requirements and to certify hydrogen according to its designated classification. In addition, both regulatory reporting and certification need to include all emissions scopes as defined by IPCC and GHG Protocol:

- **Scope 1:** direct emissions from production, storage, and transport
- **Scope 2:** indirect emission describing any offsite emissions related to energy such as electricity
- **Scope 3:** carbon footprint and emissions from purchased goods and service or support function

In addition to greenhouse gases such as carbon dioxide, methane, nitrous oxides, and CFC, other harmful components present at any stage of the hydrogen manufacturing and transport chain will require monitoring. The level of monitoring and detection will depend on the raw material of hydrogen, energy source, and equipment used.

As hydrogen production matures several methodologies will be used to ensure low or carbon free operations. However, even green hydrogen might involve the use of engines and energy sources that produce GHG emissions. Since the transition away from fossil fuel dependencies will take time, new technologies such as carbon capture will be a good short- to mid-term solution to reduce direct emission contribution.

Transportation and storage will also contribute to GHG emissions and have a carbon footprint, thus they need to be included in the carbon accounting. Even if the manufacturing process is completely emissions free, any emissions from transport and storage need to be captured, monitored, and reported as they will impact how carbon intensive and renewable the product is. Transport and cargo would therefore benefit from optimization not only to reduce cost but also to ensure the lowest possible emissions.

To determine the carbon intensity of hydrogen, a broad variety of parameters and data upstream and downstream of production need to be captured. Thus, measurement and monitoring go beyond measuring hydrogen produced and the energy used in the process. It is worth mentioning that within Europe's CertifHy™ consortium [10] , an initiative of the European Commission, two standards for renewable hydrogen were defined: Green hydrogen and Low Carbon hydrogen.

CertifHy™ Green hydrogen is hydrogen that originated from renewable sources. It is defined in article 2 of the Renewable Energy Directive II, 11 as having a greenhouse gas balance below a defined threshold, which is a minimum of 60% below the production of hydrogen through steam reforming of natural gas with a current GHG footprint of 91 gCO_2eq/MJ. This GHG intensity will be re-assessed, as the emission reduction targets evolve over time.

CertifHy™ Low-Carbon hydrogen is hydrogen that originated from non-renewable sources, nuclear, or fossil energy using carbon capture and storage (CCS) and potentially carbon capture and utilization (CCU). The greenhouse gas threshold for this type of hydrogen has yet to be defined by European Law.

A certification process is in place to use Guaranty of Origin Certificates (CertifHy™ GOs). These certificates guarantee that the hydrogen produced meets the carbon intensity requirements associated with it. A certifying authority issues the certificates to the hydrogen producers by production batches. An audit process takes place during the verification of the certificate request and before the certificate is issued.

The certificates themselves can be traded, like with Green Electricity Certificates of Origin, and have a monetary value. This provides another source of income for hydrogen producers. This certification process introduces the need for information systems to capture large volumes of measurement, sample laboratory, and operational data and ensure the data is auditable, stored, and processed securely.

These system requirements are comparable to those requirements used in the conventional upstream and midstream oil and gas sectors. Energy Components hydrocarbon Accounting and Management solutions are designed to handle these specific requirements.

Use Case	Solution Capabilities
Carbon intensity allocation and footprint documentation	EC tracks the full carbon intensity of the hydrogen value chain, including all emissions from the feedstock, the hydrogen production itself, transport, storage, and distribution.
Emission monitoring	Depending on the production method of hydrogen, different types of emissions and byproducts are created, such as CO, CO_2, residual hydrocarbons, inert gasses, oxygen, and wastewater. EC supports the monitoring, accounting, and reporting of these products and their emissions.

Use Case	Solution Capabilities
Scope 1 Direct emissions	EC calculates emissions from emission factors or from measured emitted gas components such as CO_2 and other emissions from manufacturing or supporting equipment running on fossil fuel.
Scope 2 Indirect emissions	EC tracks offsite and onsite electricity usage, which allows emissions to be calculated based on their emission factors derived from the mix of fossil energy converted to electricity.

Hydrogen Exchange

To trade hydrogen as a commodity, a market or exchange needs to be developed like it has for other commodities. A market has several requirements to be successful.

First, the market needs a physical infrastructure. There needs to be an opportunity for suppliers and consumers of hydrogen to physically exchange hydrogen. Hence, there needs to be a transport network and storage facilities. This network needs to have open access, allowing consumers to buy hydrogen from different producers and balance supply and demand.

An exchange also requires price indices to make prices transparent and to promote trading. These indices should reflect the cost to produce hydrogen and the certificates of origin. The indices are used on the spot market and enable the balance of supply and demand. In the Netherlands, the Transport System Operator for Natural Gas, Gasunie is building a hydrogen exchange: HyXchange. [12]

The next chapters provide an in-depth review of how Energy Components by Quorum Software (EC) supports the various business process of the hydrogen

Hydrogen Production

EC Production focuses on primary production of energy carriers until delivery to an intermediate storage able to be transported to the next location. The main task of EC Production is tracking the quantities of production from each source and aligning those values with what is finally sold and transported away from the facility.

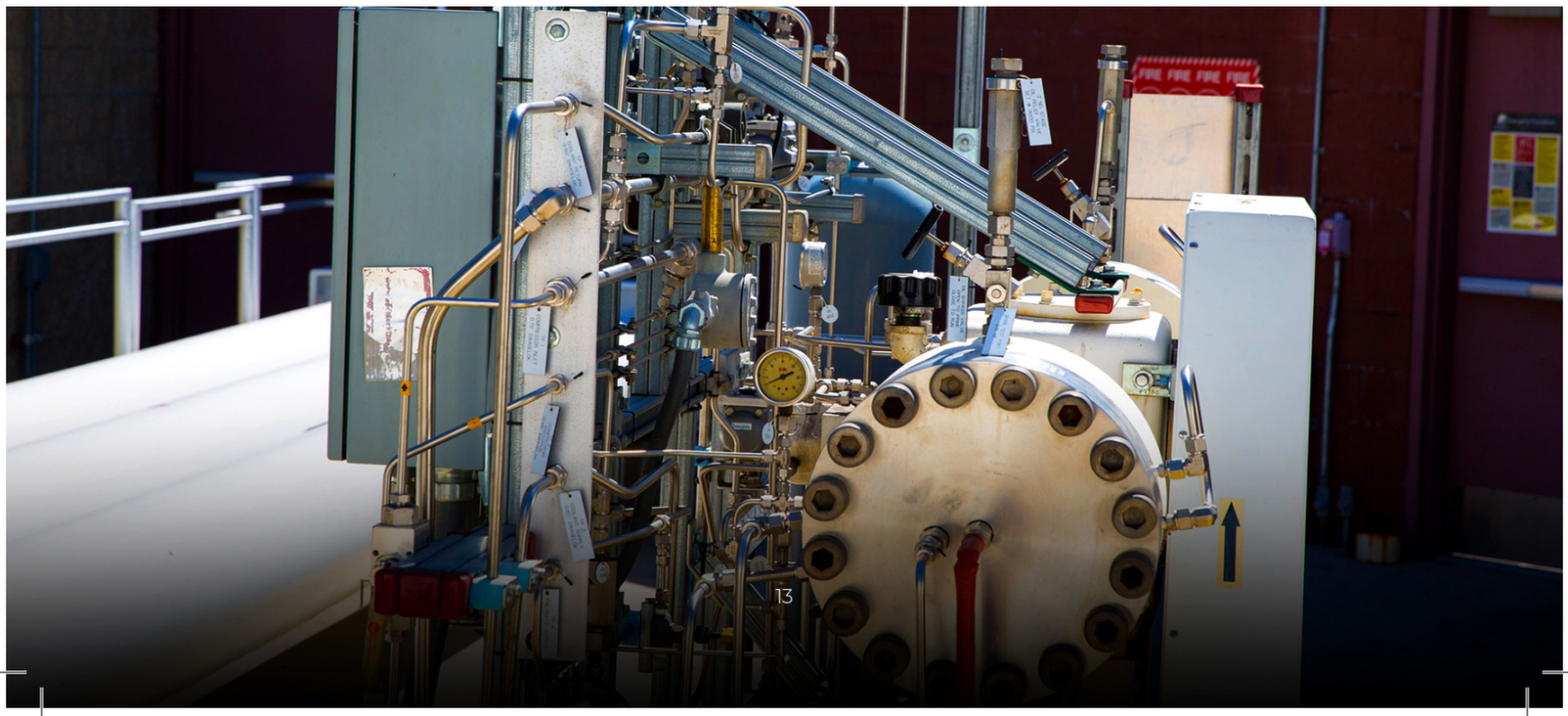
Production Management

Depending on how hydrogen is produced, the accounting and data management requirements will have some differences but the bulk of the requirements will be similar. Requirements will derive from the internal desire to steer and optimize the production process, handle sales and revenue, and address external requirements such as regulatory and compliance.

In all production methods, a data historian will gather vast amounts of data from SCADA systems. This data will require processing to create value and this processing should be handled in a system designed specifically for the energy industry that accounts and manages energy production. In addition, laboratory analysis will be central in monitoring manufacturing process health, as well as certifying the quality of the end-product.

Within the energy industry, there is a clear agenda and a variety of initiatives to increase the value derived from data. Overtaking oil as the world's most valuable resource, data is the driver for advanced analytics and decision support, helping energy companies avoid unplanned downtime and losses in productivity. These data and analytics will be especially important for improving the margins of hydrogen produced via electrolysis and in meeting the requirements for Guaranty of Origin Certificates.

In the following sections, we will review a few hydrogen production methods to highlight the benefits of using energy-specific information systems such as Energy Components.



Use case	Solution Capabilities
Data historian integration	Energy Components supports integrations with different SCADA systems and Data Historians. Where these systems provide raw measurement data from the production and transportation facilities which are processed, enriched and used in Energy Components for all production and transport management processes in the hydrogen value chain.
Energy efficiency	In all methods of hydrogen creation, input energy is converted in hydrogen. This is a process associated with Losses which are to be minimized. Energy Components provides methods to determine the efficiency of energy usage in a production facility, as the first step to optimizing energy efficiency.
Production forecasting	Historical production data, market data, weather forecasts and price calculations can be combined to forecast the production of hydrogen.
Calculation engine	It is essential for hydrogen producers to perform accurate production accounting across the entire plant. EC comes with a state-of-the-art calculation framework that supports calculating the complete hydrogen-production value chain. From component composition and energy storage in a single tank, to mass balancing all energy flows through the plant: ⬡ Allocating kilograms of produced hydrogen, its composition, emissions and byproducts back to the energy and water used to create it ⬡ Providing traceable and accountable allocations to meet all regulatory requirements and enabling producers to improve their production and efficiency.

Hydrogen from Electrolysis

Considering the energy transition to net-zero emissions, electrolysis using renewable electricity is preferred to produce hydrogen. Accounting for the increased prices of natural gas, and reducing prices of renewable electricity, which even turn negative on certain occasions, producing hydrogen via electrolysis is becoming financially viable and is closing in on hydrogen from natural gas via Steam Methane Reforming. [13]

Hydrogen electrolyzers come in different forms and both Proton Exchange Membrane (PEM) and Alkaline Electrolyzers are considered as the chosen solution for large-scale electrolysis plants.

The Institute for Sustainable Process Technology [14] (ISPT) has recently published multiple reports describing both methods as technological and economically viable for large-scale electrolysis plants producing Giga Watts from electricity from offshore wind farms and solar fields for green hydrogen, or from nuclear electricity for pink hydrogen. In most cases, the electrolyzer will obtain the electricity from the existing high voltage electricity transport systems in order to be able to meet the energy demand of the plant.

PEM and Alkaline Electrolyzers perform more efficiently using water at temperatures ranging from 70 to 100 degrees centigrade. The residual heat of the electrolysis itself is a marketable commodity that can be sold to district heating networks and can be considered when determining the energy efficiency of the plant. The oxygen which is produced along with the hydrogen has a limited economical value and will typically be vented. With the electrolyzer connected to the electricity grid, the operator has the possibility to procure electricity from multiple sources: using long-term contracts with green electricity providers, procuring renewable certificates, and buying renewable electricity on the spot market at 15-minute increments. In order to guarantee and certify the hydrogen sold originates from renewable sources, solid accounting procedures and technology are required by the plant operator. Especially since the supply, availability, and thus pricing of renewable electricity can be volatile.

Renewable green or pink hydrogen will also play a large role in balancing the electricity grid and overcoming intermittency challenges. Electrolysis plants can be used to convert the surplus of renewable electricity to hydrogen. Then, the hydrogen can be stored and used directly as an energy source or converted back to electricity when required. This will provide a significantly larger storage capacity for renewable energy than batteries can provide, with less environmental impact.

Another advantage of combining renewable electricity with hydrogen is the ability to produce hydrogen close to sources of renewable energy such as offshore wind farms. This allows producers to re-use existing infrastructure and reduces the impact on the grid. More on this subject is provided in the section Small-Scale hydrogen.

Other than electricity, large amounts of demineralized water are required to produce hydrogen from electrolysis. The usage of water in the process needs to be accounted for as well as it affects costs and handling of wastewater. Water purification and treatment need to be accounted for to provide a complete view of the certification process and meet regulatory requirements.

In addition to the general production management capabilities already mentioned, the following are specific to this production method:

Use Case	Solution Capabilities
Electricity nomination, allocation and measurement data processing	The electricity used by the electrolysis plant can be tracked on many levels: ⬡ It is possible to manage the nominated electricity quantities and compare them with the allocated quantities as they are received from the electricity grid operator. ⬡ Store the actual measured electricity usage at multiple stages and points in the plant and use these data as input for the different allocations and calculations of the hydrogen production process.
Hydrogen energy back-allocation to electricity sources	The produced hydrogen units of energy can be allocated back to different electricity contracts to determine the cost of the used electricity per kWh or kg hydrogen. This also allows to trace the produced hydrogen back to specific sources of renewable electricity based upon the measured electricity input, electricity nominations and allocated electricity. This provides an auditable solution to trace the renewable composition of hydrogen.
Use weather data in electricity price forecasts	Weather data can be stored and used in Energy Components to forecast electricity prices.
Monitoring water usage	With water as source of hydrogen manufacturing, Energy Component can track water being put into the manufacturing process, heat exchanged, and distributed. Where seawater is used, Energy Component can track water analysis before and after desalination to verify the purity of the used water.
Water treatment and wastewater	When water cannot be re-used or distributed, Energy Components tracks the water and generates water quality reports and certificates from water analysis.

Hydrogen from Fossil Fuels

Today, the most used method to produce hydrogen is Steam Methane Reforming (SMR). In this process, grey hydrogen is created from natural gas. Carbon dioxide is a byproduct of this process. For each ton of hydrogen, 11 tons of carbon dioxide are produced. Fortunately, it is possible to abate the majority of the CO_2 with Carbon Capture and Storage (CCS). Combining grey hydrogen production with CCS creates blue hydrogen. The incremental cost of CCS is small. Grey hydrogen currently costs about $2/kg ($50/MWh), while blue hydrogen costs $2.5/kg ($60/MWh).

In regions with large natural gas reserves, blue hydrogen is an economical way to produce low-carbon intensity hydrogen. Since renewable electricity is not sufficiently available to produce green hydrogen on a global scale, blue and grey hydrogen can drive the transition to green hydrogen by enabling a market demand for hydrogen as an alternative to fossil fuels. It is worth mentioning bio-hydrogen, which uses biogases as a feedstock is also considered renewable. However, this type of hydrogen production is still nascent and biofuel production competes with agricultural land and other scarce resources.

Using hydrocarbons to manufacture hydrogen should be the last option, as it will add to direct emissions. To proceed with this type of production, it is necessary to estimate, measure, and abate all emissions such as CO_2, methane, nitrous oxide as well as harmful non-GHG substances. Adding carbon capture technologies and monitoring leakage and venting is a necessity because methane and nitrous oxide have much higher global warming potential (GWP) value than CO_2.

Use Case	Solution Capabilities
Feed gas nomination, allocation and measurement data processing	The feed gas used in the process can be tracked on multiple levels and for multiple purposes: ⬡ It is possible to manage the nominated feed gas quantities and compare them with the allocated quantities as they are received from the pipeline grid operator or upstream gas producers. ⬡ Store the actual measured gas usage at multiple stages and points in the plant and use all this data as input for the different allocations and calculations in the hydrogen production process.
Hydrogen energy back-allocation to feed gas sources	The produced hydrogen units of energy can be allocated back to different feed gas contracts to determine the cost of the used feed gas per kWh or kg hydrogen. This also allows traceability of the produced hydrogen back to specific sources of feed gas which have different carbon footprints. Based upon the measured input, feed gas nominations, and allocated feed gas, it is possible to trace renewable composition of hydrogen.
CCS	EC is used extensively by upstream oil & gas producers in managing injection of CO_2 into the ground for reservoir pressure maintenance and enhanced production. This functionality can also be used to track carbon capture and storage from hydrogen production should the plant have such technology and capabilities to inject captured carbon into e.g. nearby underground caverns. If CCS is managed as a commercial commodity, involving contractual obligations and rights concerning capacity to store and/or transport CO_2 using the infrastructure of another party, Energy Components supports the same business processes related to transportation, storage and contract management of such commodities The carbon footprint coming from the CCS process can also be managed and calculated in EC Environmental. It handles information about both captured and non-captured CO_2 and other related emissions and leaks.

Small Scale Hydrogen

Small-scale hydrogen production is hydrogen produced using relatively small electrolysis systems, close to renewable electricity sources such as offshore wind farms or solar fields.

Balancing the supply and demand of renewable electricity and the congestion of the electricity grid is becoming an increasing challenge in the energy transition. As already mentioned in the hydrogen from Electrolysis section, producing hydrogen from the electricity surplus can balance the electricity grid. In addition to this, small-scale hydrogen can resolve congestion problems by producing hydrogen close to electricity sources. Reducing the need for peak capacity on the electricity grid. These small-scale electrolyzers could be combined with fuel cells which can convert the hydrogen back to electricity. This allows a surplus of electricity to be converted and stored as hydrogen, to be able to convert it back to electricity when there is a shortage.

Neptune Energy[15] is piloting this concept in its PosHydon project where hydrogen is produced using electricity and seawater on the offshore Q13A gas platform in the Dutch sector of the North Sea. The produced hydrogen is blended with the natural gas produced on the platform and transported to the mainland. This allows for the re-use of existing offshore assets, while at the same time reducing the need for electricity transport capacity by connecting offshore wind turbines directly to the platform and its electrolyzer.

In addition to general production management capabilities already mentioned, the following are specific to this production method:

Use Case	Solution Capabilities
Integrated conventional hydrocarbon and hydrogen production	For those that have existing hydrocarbon production, the requirements for hydrogen can be handled within the same EC Production instance. The existing production allocations can be extended with specific calculations for the electrolyzer and the hydrogen produced.
Transport management of blended hydrogen and natural gas	Existing transport allocations can be extended to include hydrogen-only or hydrogen blended in with natural gas.
Small-scale hydrogen production networks and clusters	Multiple small-scale hydrogen plants can be managed from a single EC installation, comparable to conventional hydrocarbon production assets, where multiple facilities and fields are handled in a single system. Multiple allocation networks can be created to model and allocate the produced hydrogen from multiple small-scale hydrogen plants. Including all other functionality available for large-scale hydrogen or conventional hydrocarbons.

Plant Management and CMMS

Any type of production plant or processing plant requires a plant management system or Computerized Maintenance Management Systems (CMMS) to ensure safe and efficient operations of daily and ad-hoc activities. Such systems typically support asset management, work order management, preventive maintenance, labor and material cost estimations, and also design and construction assistance for new facilities.

Energy Components will integrate to inform decision-making and reporting. For instance, one might want to evaluate the commercial impact of planned maintenance cycles or look for opportunities to improve the commercial performance of the operation.

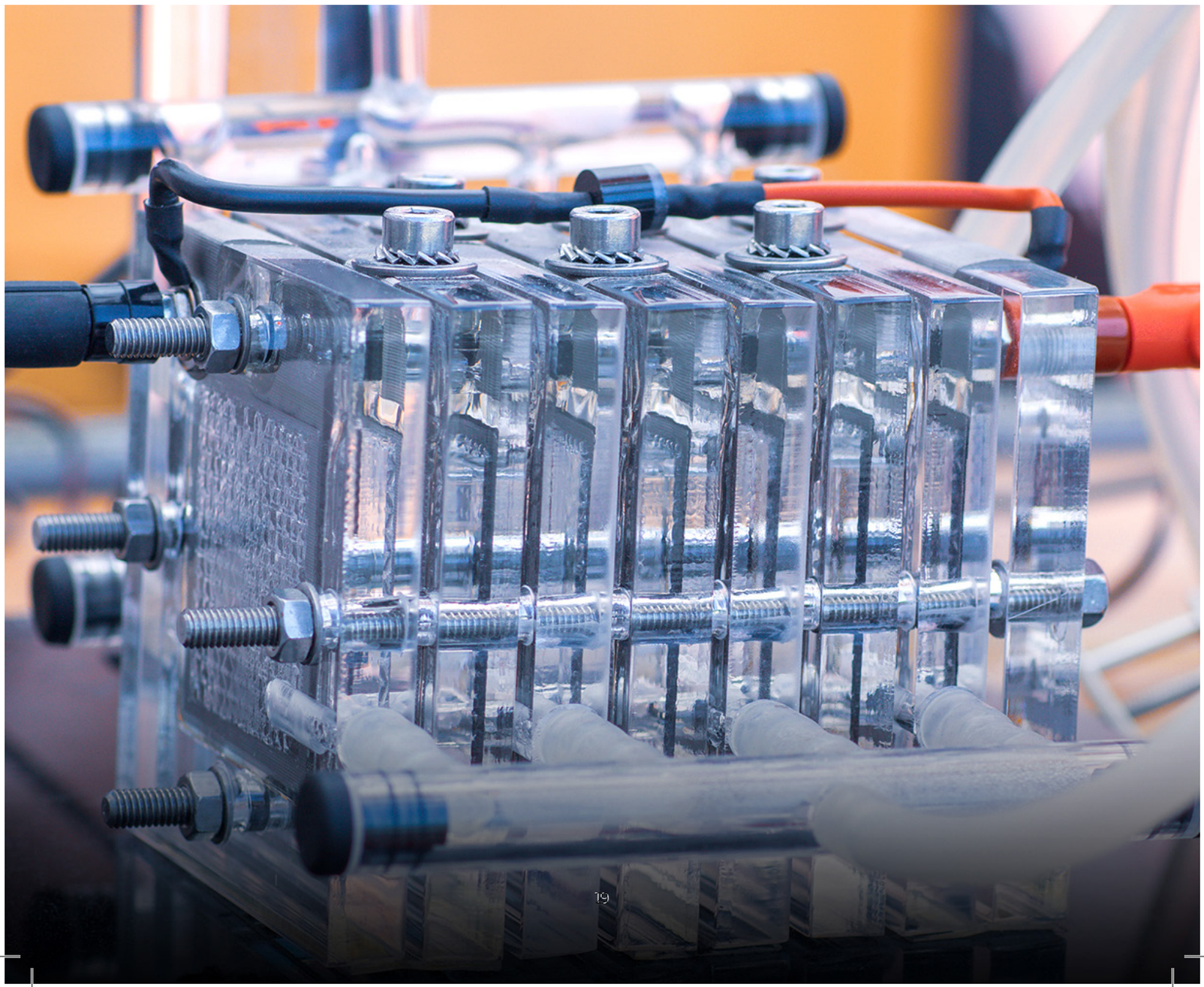
Use Case	Solution Capabilities
Maintenance Planning	Maintenance planning is key to ensure operational safety and efficiency but can also have direct impact on commercial obligations and financial performance. The key to ensure that maintenance plans and maintenance cycles will not have unintended consequences on the overall performance of the operation is to ensure that they are carefully evaluated against commercial, logistical, and financial KPIs. By loading maintenance plans into EC, the impact of proposed plans can be evaluated before the maintenance plan is approved and put into action.
Operational reporting	Operational reporting on daily and monthly basis usually contains a wide range of information ranging from operational data, production quantities, and commercial transactions and performance. Part of the content is often driven by regulatory requirements while other parts are driven by operational and commercial KPIs. EC is typically considered the system of record of the underlying data for such reports, and can also be used to produce, review, approve, and distribute the actual reports.

Laboratory sample, analysis, and quality management

In any manufacturing process, involving fluids and reaction, sampling and analysis are central to optimizing operations. For example, there is a need to verify the salt content of seawater before and after desalination to certify its purity before hydrolysis. In addition, periodic data sampling and analysis of the final product are required to certify its purity.

Laboratory and inline analysis are usually managed according to published ISO standards such as ISO14678:2019 that specify the minimum quality characteristics of hydrogen fuel as distributed for utilization in vehicular and stationary applications. There is a range of other application-specific purity specifications such as the carbon monoxide and hydrogen sulfide content in fuel cells. Many of these standards are easy to achieve with electrolysis but more challenging to the Steam Methane Reforming (SMR) process.

Energy Components include laboratory features for sample management, laboratory analysis and inline analysis



Use Case	Solution Capabilities
Sampling	Automatically generate sample schedules. Manage and track critical samples to onsite or external laboratories.
Analysis	Register and manage analysis from onsite or external laboratories, Import from other LIMS or use templates and automation to register analysis.
Verify and review	With EC Reporting and Analytics, verify analysis KPI's, view trends or compare to operational parameters. Create analysis certificate for the process or product as proof of quality or verify regulatory requirements.

Chemical Management

Chemicals are likely to be used in different manufacturing stages such as electrolysis, catalyst, production plant protection, purification, and more. Although catalysis, purification, and protection could be achieved with solids or mechanical means, chemicals may be required to improve or optimize parts of the process. For example, corrosion protection for hydrogen embrittlement where pipe and equipment coating may be too expensive and cathodic protection ineffective. Gas treatment chemicals might be required for grey and blue hydrogen to ensure the purity of the natural gas. The CO_2 capture process may require corrosion protection within a processing facility, where the CO_2 gets into contact with water, leading to carbonic acid, which is highly corrosive.

As a result, there is a need to monitor and track the cost, performance, and disposal of these chemicals:

Use Case	Solution Capabilities
Chemical inventory	Record and monitor chemical stock on storage and feed tanks. Manage small volumes in storage. View status and create chemical orders.
Chemical usage	Record usage of chemical that is continuously used in process/manufacturing or added as batches. Record and track usage across multiple facility equipment and location.
Chemical performance	Verify dosages with analysis and operational parameters to verify the effect of chemicals and uncover potential problems.

Transportation & Storage

Eventually, the hydrogen will need to be transported to the end consumers or stored. Transport and storage options and processes are similar to those of natural gas. Much of the transport infrastructure used for natural gas is suitable for hydrogen transport with limited technical changes. There is also the possibility to store and transport hydrogen in the form of ammonia.

EC Transport keeps track of reactants and products when they are transported through pipelines, marine vessels, or land from the production site to the point of sale. It tracks product inputs and outputs at multiple entry and exit points. EC Transport also manages processing terminals, which are often integrated into the transport system.

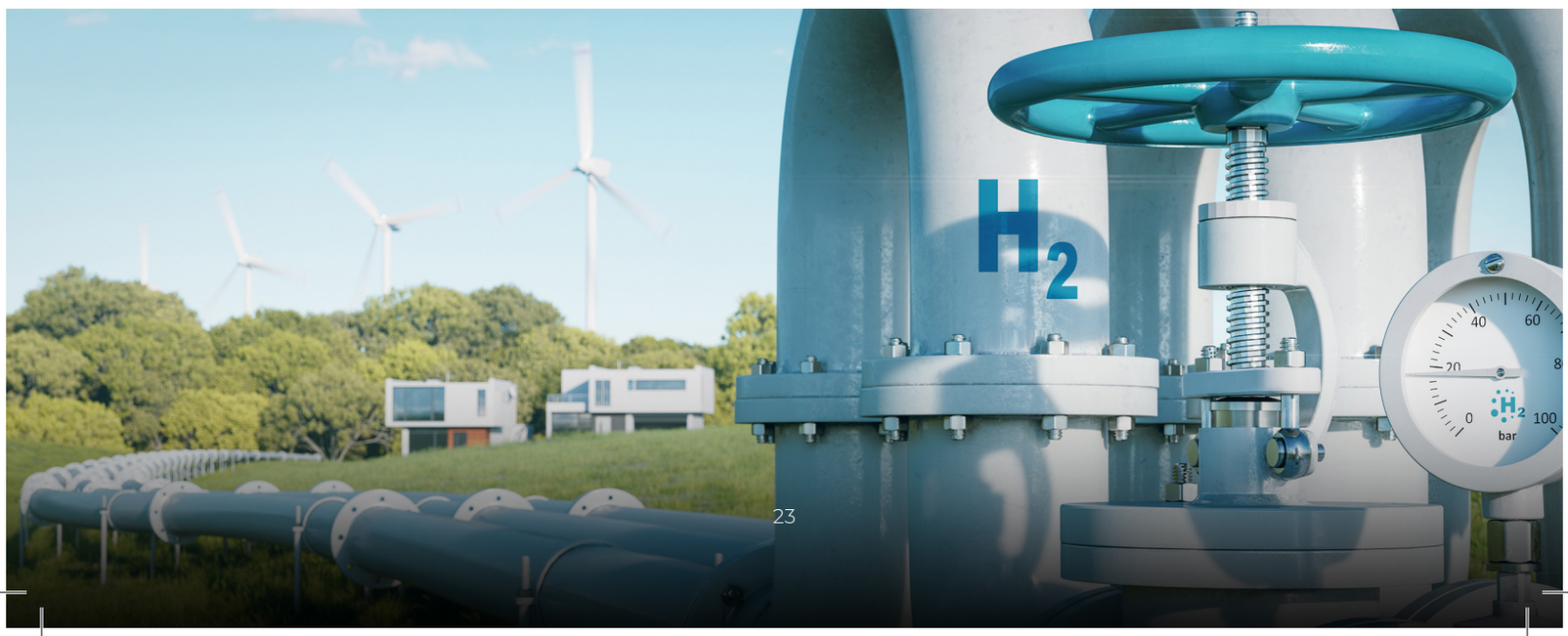
Pipeline Grid Operation

Hydrogen can be transported via pipelines, either through dedicated hydrogen pipelines transporting 100% hydrogen, or pipelines in which hydrogen is mixed with natural gas. Experiments have been conducted where hydrogen is mixed in existing natural gas distribution and transport systems, delivering up to 20% hydrogen by volume to end-consumers with no impact on the consumer.

A concern when transporting hydrogen via natural gas pipelines is that hydrogen is capable of corroding the pipes made of carbon steel. Therefore, the quality of the steel used is key. Softer steel has a more disordered atomic lattice, which ensures the hydrogen can do less damage. In Europe, most Natural Gas pipelines are made from softer steel grades and are very thick. In Italy, Società NAzionale Metanodotti (SNAM), owner of the national grid for natural gas, has calculated that at least 70% of its pipelines are ready to transport 100% hydrogen[16].

Hydrogen, of all sources, will likely be transported via common pipeline grids and serve as the backbone to consumers, industry, storage, and export. The pipeline operator is responsible for the safe and accurate transport of hydrogen, natural gas, or its combination to the shippers using its pipelines.

For every pipeline scale, grid type, and product combination, Energy Components supports the functionality required for hourly, daily, and monthly processes:



Use Case	Solution Capabilities
Capacity booking and trading	Handle the processes around the capacity from different contracts and nomination points used by shippers on your pipeline. Track capacity trades, restrictions and usage.
Nominations, matching and confirmations	Shippers submit their nominations to pipeline operators' EC system for the transport of their hydrogen through the pipelines, either as separate entry- and exit-nominations, or in a configuration where the pipeline operator determines the required counter nominations based upon the received nominations. After validating the nominations and matching with Neighboring Network Operators, either upstream or downstream, EC sends the shippers their confirmations and are ready to ship their hydrogen through the pipeline system.
Trading	Trade hydrogen and conventional hydrocarbons on pipelines, where the ownership of the product changes at the entry- or exit-nomination points Allow shippers to sell their hydrogen to other downstream operators
Allocations, Sample management, accountability	The EC allocation engine supports all calculations required for a transmission grid operator, allocating the measured hydrogen to shippers, taking into account composition samples, the greenness of the hydrogen and supporting a fully accountable transport of hydrogen from different renewable sources from their production to the receiving customers.

Marine Transportation

Although green hydrogen, in theory, could be produced anywhere in the world, it will be more cost-effective, if it is produced near an abundant renewable and clean water source. Ideally, each part of the world should adapt to its regional assets. For example, in the Sahara desert, placing solar panels covering a surface of around 335km^2 could be enough to power the world [17]. The North Sea is ideal for green hydrogen production due to the abundance of wind energy. Blue hydrogen is most affordable in Russia and Abu Dhabi where there are large natural gas reserves. In situations where pipeline is not available, hydrogen can be transported across countries via marine vessel.

In a marine vessel, hydrogen molecules could be transported either as liquefied pure hydrogen, stored at very low temperatures, on purpose-built marine tankers, or transported by traditional chemical tanker ships after converting hydrogen into more stable hydrogen-carrying chemicals such as methylcyclohexane (C_7H_{14}) or ammonia (NH_3). Either way, marine transportation will involve critical complex business processes related to planning, scheduling, cargo management, and terminal operations that would be similar to how hydrocarbon-based fuels such as crude oil, LPG, and LNG are handled today. In most cases, the ports and berths involved in the current hydrocarbon marine transport will also undergo their own transition towards handling renewable liquid fuels and expect to be able to handle both types of cargoes for a significant period.

Energy Components handles these business processes for both export terminals and import terminals, as well as the management of complex marine voyages between terminals.

Use Case	Solution Capabilities
Planning, scheduling & cargo management	Manage an optimized portfolio-wide long-term (typically 1 year) and short-term (typically 3 months) lifting and delivery plan for efficient operations. Create increased profitability by facilitating optimized robust plans by: ⬡ Feasible delivery schedule without any conflicts ⬡ Optimized use of berth allocation and logistics ⬡ Optimized send-out schedules for import terminals. ⬡ Efficient scenario management and analyses KPI-driven evaluation and analysis provide tremendous value to our customers.
Efficient Terminal Operations	EC provides several business functions for activities related to marine unloading and re-loading operations. All these activities can be managed through business process automation: ⬡ Cargo analysis ⬡ Bill of Lading Info / Unload Info ⬡ Timesheet / Port Log ⬡ Cargo documents generation and upload demurrage ⬡ calculations

Ground Transportation

Ground transportation by truck or rail will be the preferred mode of transportation for regional or local distribution of hydrogen molecule carriers in liquid form. This mode of transportation will be key for the adoption of small-scale hydrogen and can be used to provide liquid hydrogen to fueling stations and other industrial use. It could also be an option to transport hydrogen in gaseous form after compression.

Ground transportation requires a different approach to planning, scheduling, cargo management and terminal operations than marine transportation since the product quantities and loading windows are very different. For instance, the planning cycle will typically be much shorter, and the slot and truck services management will be more important than product quantity management than for mid- and large-scale terminals. Cargo documentation is also typically less complex and less comprehensive for ground transportation.

However, the business processes related to ground transportation is similar to that of LNG, and Energy Components is capable of handling these business processes for both export terminals and import terminals.

Use Case	Solution Capabilities
Planning, Scheduling & Slot Management	Optimized slot management and long-term and short-term loading/unloading plan are key inputs for efficient operations. Creating increased profitability by facilitating optimized robust plans are made possible by: ⬡ Feasible loading schedule without conflicts ⬡ Optimized use of slot allocation and logistics ⬡ Efficient scenario management and analysis KPI-driven evaluation and analysis provide tremendous value to our customers.
Efficient terminal operations	EC provides several business functions for activities related to unloading and re-loading operations for trucks and railcars. All these activities can be managed by business process automation: ⬡ Cargo analysis ⬡ Loading/Unloading Ticket generation and upload ⬡ Cool-down services ⬡ Truck & driver approval services ⬡ Demurrage calculations

Storage

Hydrogen can be stored in large volumes in different ways, which makes it a good option to solve seasonal energy demand fluctuations.

Pipelines used to transport hydrogen in gaseous form can be used to store hydrogen by using linepack flexibility. This is the ability to temporarily increase or decrease the pressure at which gas is transported in the grid and thus its hydrogen content. Substantial differences between supply and demand can be bridged for several hours that way.

Long-term storage to cover seasonal demand can be achieved by storing gaseous hydrogen in underground salt caverns. An example of this is the HyStock storage located in the northern Netherlands scheduled to be operational in 2026[18]. In Texas and the UK, hydrogen is already stored in salt caverns.[19].

Depleted gas fields may eventually be used as well but a limited number of experiments have been conducted and the technology needs to mature[20] before it is expected to be available for usage.

Apart from the operational benefits of storing hydrogen, there are several profitable business cases tied to these storage facilities. In an open hydrogen economy, storage can be shared by multiple parties such as shippers and traders. The storage capacity, as well as injection and production capacity, can be marketed as products. In this context, production refers to the extraction of existing hydrogen from a storage facility, not to the creation of new hydrogen molecules from other sources.

Since the stored hydrogen will come from different sources and owners, it will be required to track each owners' inventory positions, balances, and reserved capacity while also keeping track of the hydrogen's carbon intensity.

Storage also provides the opportunity for trading and ownership transfer. The information sytem of the storage operator will have additional requirements related to accountability, compliance, transparency, and integration into the systems of the hydrogen shippers and traders.

All of this requires a software solution that provides accounting and transparency, and the ability to connect to shippers and trading systems. Energy Components manages the storage of hydrogen pipelines, large storage, and salt caverns, including those for trading.

Use Case	Solution Capabilities
Stock positions and entitlement	Based upon measurements, nominations and transport allocations of injection into storage and production from storage.
Account balance tracking	When injecting or producing hydrogen for storage, the actual measured and allocated quantities will vary from the intended and nominated quantities. Operational requirements, to balance the pipeline system can result in Stock Account Balance positions or Operational Balances. EC supports the calculations and tracking of these balances for all involved parties and allows them to be communicated to third parties via EDI messages such as what is done for Natural Gas through ACCPOS G@SDAT messages.
Transfer of ownership	Ownership of hydrogen in storage can be tracked in EC via different methods. The Class Model supports tracking ownership on different dimensions such as company and profit centers. Customers of the storage facility, their contracts, and virtual nomination points are configured, after which this information can be used to transfer hydrogen from a seller to a buyer.
Invoicing of storage capacity usage	Based upon the business model of the hydrogen storage facility, the operator can invoice the storage capacity users. This could be based upon used injection and production capacity, the stock positions, reserved capacity, balance positions or combinations of all these items. EC can process and generate these invoices.
Pipeline dispatching	Where large hydrogen storage is connected to hydrogen transport pipelines, the dispatching of hydrogen transport on these pipelines is closely related to the dispatching of the storage facility. EC supports the complex processes such as nominations, matching, allocations and account balance tracking.

Sales, Revenue & Commercial Management

EC Sales is the part of Energy Components that manages contractual commitments and pricing. The main function of EC Sales is to track quantities of gas and liquid sold and calculate the portion that needs to be invoiced at the end of the monthly or quarterly close cycle.

Once the sold products have been delivered, it is essential to invoice for all sales according to the contract terms and to properly account for all revenue from those sales. This is referred to as the contract to cash process and is handled in EC Revenue. Likewise, if products are purchased from third parties, it also important to account for the receipt of those products and their price.

Commercial Management

Various commercial models could be viable for large-scale hydrogen production and distribution, but most likely, the models will involve several parties, each focusing one part of the value chain. Some companies will focus on green electricity production, while others will focus on hydrogen production. The latter may also operate marine terminals, while others will operate the pipeline. Further specialists will exist in small-scale hydrogen production and distribution.

While some companies will be involved in the direct sale and purchase of reactants, process outputs and end user products, others will likely focus on providing third parties access to infrastructure through tolling agreements or energy conversion agreements. These types of contracts are already common in the energy industry to reduce risk and provide focus for the individual businesses who seek optimal use of costly infrastructure.

Furthermore, it is likely that ownership of many production plants, terminals, and distribution networks will be set up as joint ventures, especially in the early stages of the hydrogen economy where the risks are still high. With multiple participating parties, ownership structures and commercial models, robust and auditable energy accounting software will be critical.

Use Case	Solution Capabilities
Contract management	Actual agreements between hydrogen companies and their business partners will be managed and maintained using the flexible contract concept in EC. This can be any type of contract, such as: ⬡ Sales and Purchase Agreements (SPA) ⬡ Inter-Company Agreements ⬡ Various Terminal Agreements Any amendments to contracts can be maintained using contract attribute parameters.

Use Case	Solution Capabilities
Entitlements & ownership allocation	EC provides built-in functionality for entitlement calculations and ownership allocation for setups that involves joint-ventures or other forms of shared infrastructure. This type of commercial allocation can be configured to correctly allocate the carbon intensity of shared process outputs between inputs that belong to different commercial entities.
Borrowing & Lending	Standardized functionality to handle borrowing and lending is provided by EC, and specific commercial rules and calculations defined by individual contracts can be configured using the calculation framework.
Deadline Management	Contract and deadline management functionality is key to handle various commercial activities within certain deadlines to avoid suboptimal operation or financial penalties.

Pipeline Shipping

For hydrogen shippers, Energy Components supports complete transportation processes of hydrogen via pipelines, starting with forecasting and planning of the hydrogen dispatching via nominations, matching, allocations and reconciliations to the final invoice.

Typically, the transport of hydrogen and natural gas, or mixtures of both are handled in units of energy. EC supports all calculations in energy, volume, mass, and the conversions between them based upon samples and composition data of the hydrogen and hydrocarbon mixture throughout the entire process, handling the data in the way it is expected to be used.

Use Case	Solution Capabilities
Planning and forecasting	The extensive planning and forecasting capabilities of EC manage the tracking of the future pipeline transports of hydrogen from entry points to downstream delivery points. Forecasts can be calculated from the Calculation Engine or imported from external systems.

Use Case	Solution Capabilities
Nominations	The hydrogen and natural gas nomination functionality provides extensive solutions for the pipeline nomination process including: ⬡ Generating nomination and re-nomination messages ⬡ Capturing matching results and confirmations from the pipeline operators ⬡ Path-nominations, which automatically create combinations of input- and output-nominations required to deliver the hydrogen ⬡ Balancing functionality ensuring transport contracts remain balanced
Allocations and reconciliation	Transport allocations, account balance information, and reconciliation data received from the pipeline operator are automatically processed and can be used as input for downstream processes such as contract allocations, forecasting, and invoicing.

Pricing, Invoicing & Revenue Accounting

Independent of which commercial models and contractual agreements become standard, there will be many financial transactions related to quantity, capacity, and scheduling that need to be priced, invoiced, and accounted for in an auditable way and according to best practice accounting principles. The operation will need to produce final and accrued invoices for outbound delivery and invoice verification for inbound transactions. Invoices might be generated monthly, cover multiple months, or triggered by an event, such as after cargo loading is complete.

EC Revenue provides a solution for automated invoice processing and recognizes revenues from various services. It includes a two-way interface with financial accounting systems. The solution supports automatic consistency checks and governance with segregation of duties including multi-leveled approvals. . Cost handling, inventory valuation, and forecasting of quantity and revenue is also supported.

EC Revenue can support the whole hydrogen production value chain from feedstock to accounting. The module automates as many of the commercial and financial tasks to reduce the need for manual entry.

Use Case	Solution Capabilities
Price determination	An integral part of any invoice verification process is to determine the correct price based on contractual agreements. When these contractual agreements are modeled in EC, the price formulas can also be configured in the solution to provide automatically calculated prices for each invoice. Typical inputs to price determination can be various price indices such as currency rates and interest rates.
Financial transactions	EC captures, calculates, and books all equity share sales, purchases and tariffs by profit center and contract. The solution supports single step invoicing where final price and final quantity is known at the point of invoicing, or multi-step invoicing where there is a change in price and/or quantity after the first invoice has been generated. Corrections using delta invoicing, full reversal and new full invoice, or single invoice with prior period adjustments is also supported.
Cost handling	EC can interface and store all kind of cost associated to an asset or installation. The cost pool can be downloaded from the ERP system and used for revenue accounting should this be required for the operation, with full support for prior-period adjustments.
Inventory valuation	EC can track inventory quantities and monetary valuation of under-lifting, over-lifting and the physical stock. Stock positions can be tracked in terms of both quantity and value, including storage tanks, line-fill, banking, and goods-in-transit. The closing balance can be evaluated in EC and posted to the ERP system
Forecasting	The EC Revenue module supports forecasting of both quantities and revenues for each profit center and product based on forecasted sales, purchases, and inventory positions. Annual plans can be created using this functionality, and monthly closing forecasts combining actual and forecasted data can be produced.
Quantity Management	EC Revenue has its own Quantity Module that captures and calculates quantity data, and this information is then shared between the functional areas within EC Revenue. Production, sales, tariff, and inventory reconciliation can then be performed. Using “stream items”, all kinds of quantities associated to profit center, and legal entities can be handled. The stream item contains information about owner equity share(s), source(s), product(s) and other relevant information based on local business requirements.

Maximizing Profitability & Utilization

By using advanced analytics frameworks which encompass optimization algorithms, simulations, learning algorithms, and combined models, the EC software helps to make the most optimal decisions for both short-term and long-term considerations. This can encompass the whole hydrogen value chain or parts of it, depending on requirements and business case.

Examples of optimization and decision support opportunities by using the EC software are for terminals are:

- Accommodate as many throughput Customers as possible within the asset and scheduling constraints of the terminal for terminal operations.
- Support developing terminal access code(s) to set up rules for accessing the terminal on a spot basis
- Optimization and decision-making support regarding excess cargoes opportunities in addition to the contracted customer capacity and optimization cargo planning
- Utilize as much unload, reload, storage, and send-out capacity throughout the Contract Year by optimizing the long-term schedule, short-term schedule, and daily operations process
- Decision support regarding making new Terminal Agreements by identifying gaps and scheduling bottlenecks with having alignment across all contracts
- Decision-making support with unexpected events, proposing the most optimal solution based on constraints, contracts, regulations, and physical capacity
- Simulation of scenarios to create a sustainable long-term schedule considering new and existing Terminal Agreement rules and other variables like opening balances, ship sizes, and send-out quantities

Customer Portal

The web-based portal, which is a part of the EC solution for hydrogen marketing operations enables the communication between the hydrogen company and its customers. Customers have secured access to the customer portal. It is the “single source of truth” for the exchange of information between the hydrogen-producing company and its customers and data published to the customer portal will be available to all customers instantly.

The bi-directional communication between the company and customers is facilitated via the portal in such a way that customers can receive notifications, view relevant information, and upload and download reports as per their requirements.

The solution provides the infrastructure for an operator to review the impact of customer requests on the current master plan, and the ability to prove that customer requests were handled and prioritized in accordance with their Sales and Purchase Agreements (SPA). The customer portal supports various business processes and functionalities involved in the hydrogen supply chain, such as:

- Exchange of information related to long-term planning and short-term scheduling processes
- Customers can submit a change request to the schedules, such as change of marine vessel, delivery window, and nominated quantity
- View cargo Information for vessel and truck loading including cargo document generation and distribution
- Submit nominations and re-nominations within nomination cycles
- Customers can view their customer-specific inventory levels and entitlements in a segregated and secure manner
- Customer can access reports, generated in EC

Task List Mobile App

A growing number of energy companies are turning to the latest technology trends, including mobile applications to optimize operations and improve organizational performance. The right mobile strategies have shown to improve business processes and reduce costs.

EC Mobile Task List lets users manage their tasks and make informed decisions from their mobile devices. Notifications are sent when an action is needed and can complete the action with only a few clicks on their phone. Information about asset performance is available through an intuitive interactive graphical interface, allowing them to view data from different perspectives and drill into the details. Furthermore, customers can design their own dashboards and reports, and then publish them for mobile use.

Business Process Management enables cross-organization interaction, where each task managed in the mobile app integrates with automated computer tasks and tasks carried out within EC. Instant notifications reduce long idle cycles, resulting in quicker process completion with less manual effort.

Tasks can be assigned to individual persons or to groups, and group tasks can be picked up by any group member. Tasks can be re-assigned until it is complete allowing for efficient collaboration and ensuring consistent handling of complex tasks.

Customers can build custom workflows in EC using visual tools, and workflow tasks are automatically visible in the EC Mobile Task List application. Process execution can be triggered directly from the mobile application such as when to start an optimization job as soon as the user discovers changed operating conditions.

Energy Components' Mobile Task List benefits a wide range of workflows. A few examples include:

- Daily supervisor verification of data, triggered by the operator completing data input
- Ordering a sample by the chemical engineer
- Completion of samples by field operator TSO
- Handling of received nomination requests from shippers
- Generation of cargo documentation or time sheet based on real-time events in the harbor
- Verification and multi-step invoice approval, triggered by completion of cargo loading

EC Mobile Task List is a progressive web application with responsive design, written in AngularJS, and runs in any browser or on Android and Apple operating systems.

Reporting and Analytics

In all stages of hydrogen production and delivery, data brings value and helps to improve quality, make informed decision, uncover potential deficiencies, and track KPIs to drive performance.

While structured data management ensure data quality and reliability, dashboards and reports offer operational insights and decision support.

Figure 2. Dashboards and reports have successfully been used with Energy Components to provide key information related to specific operations. The hydrogen production and delivery process is similar to existing energy production with key indicators that can be structured and visualized in a familiar way.

Within the Reporting and Analytics feature of EC, you can visualize and explore data. Without coding, you can easily create enterprise dashboards or provide users with templates for self-service reports and visualizations. EC offers 50 built-in chart types and formats to get you started.

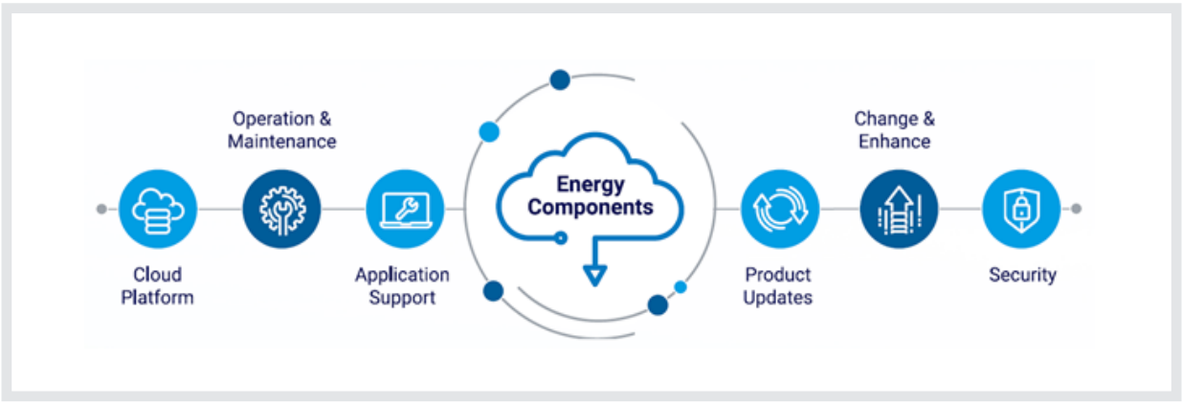
Figure 3. The flexibility of EC Reporting and Analytics enables both enterprise and self-service analytics from drag-and-drop visualizations and easy access to relevant data.

Technology & Delivery Model

Infrastructure and Integration

Energy Components-as-a-Service (ECaaS) provides an end-to-end service for our EC customers in the cloud. Our cloud service ensures that all personnel, hardware, software, licenses, and support are available as required at a well-understood and predictable cost.

ECaaS is delivered on the globally available Oil and Gas Cloud Platform. The Oil and Gas Cloud Platform is developed on top of Amazon Web Services (AWS) and is the foundation for delivering cloud services to customers. ECaaS is governed by a Service Level Agreement (SLA) that enforces the delivery of service for every customer.



EC supports a wide variety of interfaces for data import and export. It is configured to integrate with metering and tag-based solutions, importing data from laboratory analysis solutions as well as transferring data to and from process simulation tools. Furthermore, it supports the import of data from several file types.

ECIS agents are used to allow integration to the cloud without customer opening for inbound traffic to the customer's corporate network. They are lightweight standalone applications that can be placed close to the data source to extract and read data and then push these data to Energy Components in the cloud. Several ECIS agents can be installed simultaneously and independently to handle multiple data sources. For instance, one ECIS agent might be installed close to the SCADA system while another ECIS agent might be installed on a server to monitor a file-drop directory.

Please refer to a separate brochure "EC as a Service" for more details about Energy Components as a Service (ECaaS).

Standardization & Total Cost of Ownership

One of the traditional strengths of Energy Components has been its flexibility when it comes to catering for individual customer requirements and specificities through a vast range of configuration options and low-effort high-impact customizations. These strengths are also part of what enables Energy Components to provide commodity agnostic functionality and quickly adapt to new domains and market changes.

Quorum Software is currently focused on firming up the “dos and don’ts” when it comes to the solution implementation and finding manageable ways of securing a high degree of configurability without significant implications on long-term Total Cost of Ownership (TCO).

Through a high degree of modularization, standardization, and defined pre-configuration we will be able to deliver the Energy Components solution at a price point suitable for lower margin energy businesses such as LNG import and renewable fuels both when it comes to both software/SaaS subscription fees and implementation costs. This model is currently being applied to the business of LNG import and we foresee the same for renewable fuels such as hydrogen. We are also looking into multi-tenancy as a possible way forward if we can achieve the necessary level of standardization across multiple customer installations.

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