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ARGUS HYDROGEN AND FUTURE FUELS

Contents:

Argus Hydrogen and Future Fuels	2
Green (No-C)	2
Yellow (baseline)	3
Grey (baseline), Blue (Low-C and BAT+)	3
Blue (coal gasification)	5
Regional technology averages	5

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The most up-to-date Argus Hydrogen and Future Fuels methodology is available on www.argusmedia.com

Argus Hydrogen and Future Fuels

Argus Hydrogen and Future fuels includes modelled costs for hydrogen produced at newly constructed facilities using several industry standard production paths.

For each technology a standard project is modelled using assumed capital and other costs, adjusted for each location based on risk and tax rates that vary by country.

Those costs, summarised below are reviewed periodically and are subject to change from time to time as national taxation and fiscal policies change.

To those capital costs is added operating costs and the variable cost per kilogram of hydrogen. Assumptions used in determining fixed and variable costs are described below and are updated semi-annually, subject to market consultation.

Timing

Costs are calculated and published electronically each week, on Tuesday, and appear in the twice-monthly print edition of Argus Hydrogen and Future fuels.

Where daily feedstock prices are used in calculations, they are the average of prices available since the last time hydrogen costs were calculated.

Currency and unit

Prices are published in US dollars per kilogram and in the local currencies for Australia, Canada, China, Europe, India, Japan and South Korea. Currency conversions are made using an average exchange rate during the week before publication.

Capex/no-capex hydrogen costs

For each location and technology, two sets of hydrogen costs are published, one including capex and another excluding capex, allowing for clear comparisons of fixed and variable costs between locations and technologies.

Fixed cost summary

	Capex (\$/kW)	Fixed cost (\$/t H2, plant lifetime)	Capex (\$/kg H2, actual)
ALK electrolysis	1,150	373	1.15-1.22
PEM electrolysis	1,700	grid/diurnal	599
		offshore wind	699
ATR+CCS		369	0.68-1.06
SMR		151	0.28-0.44
SMR+CCS		271	0.50-0.78
Coal gasification		429	0.87-1.15

Note: Argus publishes hydrogen prices including and excluding capex, allowing for specific capex assumptions on a \$/kg of hydrogen basis to be calculated for each technology and location. Ranges of those figures are shown here and vary depending on country risk and tax rates

Green (No-C)

Green (or No-C) hydrogen is produced using renewable electricity, either generated as part of an integrated hydrogen and electricity project or purchased from the grid with an accompanying guarantee of origin.

Electrolyser assumptions

Two technologies are modelled — ALK and PEM — for which capital, operating and other costs vary by location. Both assume a 100MW plant design capacity, operating and other costs of 3.5pc of capital expense per year and a plant lifetime of 25 years. A capacity factor of 70pc is assumed for grid-connected and diurnal installations and a capacity factor of 60pc is assumed for offshore wind-powered projects.

ALK installations are assumed to require 58MWh of electricity per tonne of hydrogen and PEM installations 54MWh/t.

Electricity prices

Where available, Argus has used levelised cost of electricity figures from the International Renewable Energy Agency (Irena) for the cost of off-grid power. In some cases Argus makes an estimate of the cost based in part on Irena data.

European grid electricity prices are the Argus month-ahead base load price for the named country. See the [Argus European Electricity methodology](#).

Green (No-C) hydrogen cost assumptions

Location	Technology	Electricity source	Electricity cost source
Europe			
Netherlands	PEM	Offshore wind	Irena
Netherlands	ALK	Grid + GOO + 18pc fees	Market
UK	PEM	Offshore wind	Irena
UK	ALK	Grid + GOO + 30pc fees	Market
Germany	PEM	Offshore wind	Irena
Germany	ALK	Grid + GOO + 24.4pc fees	Market
France	PEM	Offshore wind	Argus estimate
France	ALK	Grid + GOO + 39.2pc fees	Market
Spain	PEM	Onshore wind+solar	Irena
Spain	ALK	Grid + GOO + 24.6pc fees	Market
Americas			
US west coast	PEM	Onshore wind+solar	Argus estimate
Canada	PEM	Offshore wind	Argus estimate
Brazil	PEM	Onshore wind+solar	Irena
Chile	PEM	Onshore wind+solar	Irena
Middle East and Africa			
Oman	PEM	Onshore wind+solar	Argus estimate
Qatar	PEM	Onshore wind+solar	Argus estimate
Saudi Arabia	PEM	Onshore wind+solar	Argus estimate
UAE	PEM	Onshore wind+solar	Argus estimate
Namibia	PEM	Onshore wind+solar	Argus estimate
ore	PEM	Onshore wind+solar	Argus estimate
Asia			
Japan	PEM	Offshore wind	Irena
S. Korea	PEM	Offshore wind	Irena
China	PEM	Onshore wind+solar	Irena
Australia	PEM	Onshore wind+solar	Irena
Vietnam	PEM	Offshore wind	Argus estimate
India	PEM	Onshore wind+solar	Irena

Guarantees of origin

Guarantee of origin prices for the current calendar year are added to the price of electricity, where specified. UK calculations use renewable guarantee of origin (Rego) prices and calculations for EU countries use guarantee of origin (GOO) prices. The specific Rego or GOO price used is the lowest of the relevant published unsupported Rego or GOO price assessments.

See the [Argus European Electricity methodology](#).

Grid fees

Grid fees are added to the cost of electricity for projects connected to the power grid. Fees are expressed as a percent of the wholesale power price and are reviewed semi-annually.

Yellow (baseline)

Yellow (or baseline) hydrogen is produced using grid electricity without any guarantee of origin.

Electrolyser assumptions

Two technologies are modelled — ALK and PEM — for which capital, operating and other costs vary by location. Both assume a 100MW plant design capacity, operating and other costs of 3.5pc of capital expense per year and a plant lifetime of 25 years. A capacity factor of 70pc is assumed for grid-connected and diurnal installations and a capacity factor of 60pc is assumed for offshore wind-powered projects.

ALK installations are assumed to require 58MWh of electricity per tonne of hydrogen and PEM installations 54MWh/t.

Electricity prices

Europe

The Argus month-ahead base load price for the named country. See the [Argus European Electricity methodology](#).

Yellow (baseline) hydrogen cost assumptions

Location	Technology	Electricity source
Netherlands	ALK	Grid + 18pc fees
Netherlands	PEM	Grid + 18pc fees
UK	ALK	Grid + 30pc fees
UK	PEM	Grid + 30pc fees
Germany	ALK	Grid + 24.4pc fees
Germany	PEM	Grid + 24.4pc fees
France	ALK	Grid + 39.2pc fees
France	PEM	Grid + 39.2pc fees
Spain	ALK	Grid + 24.6pc fees
Spain	PEM	Grid + 24.6pc fees
US west coast	ALK	Grid + 64pc fees
US west coast	PEM	Grid + 64pc fees
US Midwest	ALK	Grid + 69pc fees
US Midwest	PEM	Grid + 69pc fees
US east coast	ALK	Grid + 51pc fees
US east coast	PEM	Grid + 51pc fees
Japan	ALK	Grid + 47.9pc fees
Japan	PEM	Grid + 47.9pc fees

US

To produce a price for every hour in the calendar month, Argus averages peak and off peak price assessments as described below.

West coast: the Argus month-ahead off peak and peak price assessments for the NP15 market area. Peak is 06:00-22:00 on business days, off peak is all other hours.

Midwest: the Argus month-ahead off peak and peak price assessments for the northern Illinois market area. Peak is 07:00-23:00 on business days, off peak is all other hours.

East coast: the Argus month-ahead off peak and peak price assessments for the PJM West market area. Peak is 07:00-23:00 on business days, off peak is all other hours.

See the [Argus US Electricity methodology](#).

Japan

The Argus month-ahead base load price for the Tokyo market area.

See the [Argus Japan Utility Markets methodology](#).

Grey (baseline), Blue (Low-C and BAT+)

Argus publishes the cost of hydrogen produced using steam methane reforming (SMR) and autothermal reforming (ATR) processes, with or without carbon capture and storage (CCS) and with natural gas drawn from the local market, priced at regulated tariffs or bought at international market prices.

Two technologies are modelled — SMR and ATR — for which capital, operating and other costs vary by location. Argus also publishes costs excluding capex for existing SMR plants where a CCS system has been retrofitted. All assume 60,000 t/yr plant design capacity and a capacity factor of 90pc.

Assumptions per tonne of hydrogen produced

SMR without CCS

- 9t of CO₂ is released
- 3.4t of natural gas is required, including gas consumed as fuel
- 6.64t of water is consumed

SMR with CCS

- 1t of CO₂ is released
- 8.59t of CO₂ is captured and stored
- 3.74t of natural gas is required, including gas consumed as fuel
- 4.68t of water is consumed
- CO₂ transport and storage is assumed to cost \$20/t

SMR with CCS retrofit

- 2.9t of CO₂ is released
- 7.5t of CO₂ is captured and stored
- 3.74t of natural gas is required, including gas consumed as fuel
- 4.68t of water is consumed
- CO₂ transport and storage is assumed to cost \$20/t

ATR with CCS

- 0.6t of CO₂ is released
- 9.84t of CO₂ is captured and stored
- 3.81t of natural gas is required, including gas consumed as fuel
- 2.28MWh of electricity is consumed
- 25.27t of water is consumed
- CO₂ transport and storage is assumed to cost \$20/t

Natural gas prices

Natural gas prices are converted at a fixed 48.62mn Btu/t

Europe

Netherlands: TTF day-ahead

UK: NBP day-ahead

Germany: Germany VTP (Trading Hub Europe) day-ahead

Spain: PVB front-month

France: PEG day-ahead:

See the [Argus European Natural Gas methodology](#)

North America

US Gulf coast: Henry Hub day-ahead index

Canada: Alliance ATP day-ahead index

See the [Argus Natural Gas Americas methodology](#)

Asia

Japan: LNG des northeast Asia (ANEA) first half month forward

South Korea: LNG des northeast Asia (ANEA) first half month forward

Australia: AEMO Victoria, prompt

Qatar: the higher of the published LNG fob Middle East (Asia-Pacific bound) ARV and LNG fob Middle East (Europe bound) ARV prompt prices less 5pc to account for liquefaction costs

UAE: the higher of the published LNG fob Middle East (Asia-Pacific bound) ARV and LNG fob Middle East (Europe bound) ARV prompt prices less 5pc to account for liquefaction costs

See the [Argus LNG Daily methodology](#)

Russia

Gas prices are the regional maximums for industrial consumers as set by the Federal Tariff Service of the Russian Federation

Russia west: Orenburg region

Russia east: Yamal region

Trinidad and Tobago

LNG fob Trinidad and Tobago first half month forward. See the [Argus LNG Daily methodology](#)

CO₂

Hydrogen producers are assumed to purchase allowances or pay CO₂ taxes for unabated CO₂ emissions.

EU and UK: CO₂ costs are the Argus assessments of EU ETS and UK ETS spot prices. See the [Argus European Emissions Markets methodology](#).

Japan: the Tax for Climate Mitigation, imposed by the Ministry of the Environment is added to the gas price

South Korea: the price of credits in the Korea ETS (K-ETS) scheme

Canada: priced as per the Greenhouse Gas Pollution Pricing Act

Electricity prices**Europe**

The Argus month-ahead base load price for the named country. See the [Argus European Electricity methodology](#).

Russia

The weighted average day-ahead wholesale auction price from Russian state wholesale power market trading platform operator ATS.

Russia west: Orenburg region

Russia east: Tyumenskaya region

Japan

The Argus month-ahead base load price for the Tokyo market area. See the [Argus Japan Utility Markets methodology](#).

South Korea

The Kepco tariff for high-voltage electricity consumers.

Qatar

The Qatar General Electricity and Water Corporation (KAHRAMAA) tariff for industrial electricity consumers

UAE

The Dubai Electricity and Water Authority (DEWA) tariff for industrial electricity consumers

Australia

The average Australian Energy Market Operator (AEMO) Victoria spot price

Canada

The average Alberta Electric System Operator (AESO) daily pool price

Trinidad and Tobago

Trinidad and Tobago Electricity Commission (TTEC) tariff for very large industrial consumers

US

To produce a price of electricity for every day in the calendar month, Argus averages peak and off peak price assessments as described below.

Gulf coast: the Argus day-ahead off peak and peak price assessments for the Entergy market area. Peak is 07:00-23:00 on business days, off peak is all other hours. See the [Argus US Electricity methodology](#).

Blue (coal gasification)

Argus publishes the cost of hydrogen produced using coal gasification with carbon capture and storage (CCS) and with coal purchased at international market prices.

Capital, operating and other costs vary by location. All assume 250,000 t/yr plant design capacity and a capacity factor of 90pc.

Assumptions per tonne of hydrogen produced

- 1.5t of CO₂ is released
- 17.7t CO₂ captured and stored
- 11.43t of 5,500 kcal/kg coal is consumed
- 1.36MWh/t of electricity is consumed
- 12.17t of water is consumed
- CO₂ transport and storage is assumed to cost \$20/t

Coal

Prices are the latest available

Australia

fob Newcastle 6,000kcal/kg NAR

fob Newcastle 5,500kcal/kg NAR

China

cfr south China 5,500 kcal/kg NAR

ddp Shanghai 3,800 kcal/kg NAR

South Africa

fob Richards Bay 6,000 kcal/kg NAR

fob Richards Bay 4,800 kcal/kg NAR

Indonesia

fob Indonesia 5,800 kcal/kg GAR (5,500 kcal/kg NAR)

fob Indonesia 4,200 kcal/kg GAR (3,800 kcal/kg NAR)

Russia

fob Black Sea 6,000 kcal/kg NAR

See the [Argus Coal Daily International methodology](#)

US

fob Hampton Roads terminals 6,000 kcal/kg NAR

See the [Argus Coal Daily methodology](#)

Electricity

Australia: the average Australian Energy Market Operator (AEMO) Victoria spot price

China: State Grid Corporation of China monthly tariff

South Africa: The tariff for Eskom direct customers

Indonesia: National Electricity Company PLN quarterly industrial tariff

Russia

The weighted-average day-ahead wholesale auction price from Russian state wholesale power market trading platform operator ATS.

Russia west: Orenburg region

US

To produce a price for every hour in the calendar month, Argus averages peak and off peak price assessments as described below.

East coast: the Argus month-ahead off peak and peak price assessments for the PJM West market area. Peak is 07:00-23:00 on business days, off peak is all other hours.

See the [Argus US Electricity methodology](#)

Regional technology averages

Argus also publishes regional average hydrogen costs grouped by production technology.

Each price is an average of the listed published costs, converted to US dollars per tonne.

Northwest Europe

- Baseline: Netherlands, UK and Germany SMR (no CCS)
- BAT +: Netherlands, UK and Germany SMR + CCS
- Low-C: Netherlands, UK and Germany ATR + CCS
- No-C: Netherlands, UK and Germany PEM (offshore wind)

North America

- Baseline: US Gulf coast and Canada SMR (no CCS)
- BAT +: US Gulf coast and Canada SMR + CCS
- Low-C: US Gulf coast and Canada ATR + CCS
- No-C: US West coast PEM (wind and solar) and Canada PEM (offshore wind)

Northeast Asia

- Baseline: Japan and South Korea SMR (no CCS)
- BAT +: Japan and South Korea SMR + CCS
- Low-C: Japan and South Korea ATR + CCS
- No-C: Japan, South Korea PEM (offshore wind) and China PEM (wind and solar)

Middle East

- Baseline: UAE and Qatar SMR (no CCS)
- BAT+: UAE and Qatar SMR + CCS
- Low-C: UAE and Qatar ATR + CCS
- No-C: UAE, Qatar, Saudi Arabia and Oman PEM (wind and solar)

Exporter

- Baseline: Australia, UAE, Qatar, US Gulf coast SMR (no CCS)
- BAT+: Australia, UAE, Qatar and US Gulf coast SMR + CCS
- Low-C: Australia, UAE, Qatar and US Gulf coast ATR + CCS
- No-C: US West coast, Chile, Namibia, Australia, Oman and Saudi Arabia PEM (wind and solar)

Decarbonisation spreads

Argus also publishes the difference between lower- and higher-carbon intensity production costs. Deltas are published showing the difference between No-C and BAT + costs and between BAT + and baseline costs for each of the regions described above.