India

Neutral *(no change)*

Oil and Gas

How green hydrogen can replace LNG

- We feel advanced nuclear reactors like Molten Salt Reactors (MSRs) can pave the path for industrial production of hydrogen at a cost below US$1/kg.
- High Temperature Steam Electrolysis operates at 90+% efficiency. This can nearly halve the energy needed for hydrogen production compared to current electrolyzers. But more promising technologies are also being researched.
- Industrial production of hydrogen onsite can replace natural gas usage as a feedstock in the chemical industry, especially in ammonia production.

MSR can be a promising energy generation source for industry

Molten Salt Reactor or MSR can be made very compact and even be installed as a captive source of high temperature industrial heat and electricity. As a MSR can be made very compact, it can also be produced in a factory on a large scale. This type of reactor has almost no downtime and, in our view, can run at full capacity for years together.

HTSE is the best type of electrolysis technology for industrial use

High Temperature Steam Electrolysis or HTSE will be the best technology to produce hydrogen in large volume, especially for industrial customers. HTSE operates at >90% energy efficiency. Therefore, it needs only 43.2KWh to make 1kg of hydrogen compared to 56-72KWh required for the more established, low temperature electrolysis methodologies. Of this 43.2KWh input, 6.4KWh is thermal energy input while the rest is electrical input. As heat energy is much cheaper than electricity on a per unit basis, both these factors significantly reduce the unit cost of total energy input. HTSE is also the most efficient type of electrolysis technology with >90% energy efficiency, and it can be installed within a customer's factory and even provide some low-grade heat for other purposes. However, as stated in our recent report on green hydrogen, (High LNG prices = green hydrogen viable), there is still some time until this technology becomes fully operational.

Ammonia producers are the obvious beneficiaries of cheap hydrogen

Globally, most of the ammonia is produced by steam methane reforming of natural gas. At current global prices, natural gas cost accounts for at least 50% of ammonia cost in those places where natural gas prices are cheap and at least 70% everywhere else. Also, as mentioned in our earlier report on alternative marine fuels: (Ammonia and methanol as marine fuels), ammonia will very likely replace very low sulfur fuel oil (VLSFO) in some capacity. This will nearly triple ammonia demand and hence, industrial-scale production of ammonia using MSR and HTSE-driven hydrogen will become a necessity.

Analyst(s)

Jignyasu CHASMAWALA
T (022) 22 4161 0000
E jignyasu.chasmawala@incredcapital.com

Satish KUMAR
T (91) 22 4161 1562
E satish.kumar@incredcapital.com

Hydrogen from next-generation nuclear reactors like Molten Salt Reactors (MSRs)

MSR promises to be a much cheaper on-demand source of energy for hydrogen production than renewables

Benefits of MSR-driven hydrogen production over renewables-based plants ➤

MSR produces a large quantity of high temperature heat (>500^{o}C) and hence, electricity. This makes it a suitable source of heat and electricity in chemical processes like hydrogen and ammonia production. Some key operational benefits of MSR over wind and solar energy include:

- It runs 24x7, thus eliminating the need for energy storage either in the form of batteries or as a heat storage. This reduces capital cost considerably.
- It has a very high-capacity factor (how often it can run at full capacity) and can easily manage 95-100% capacity factor compared to <30% for solar and wind power plants.
- This also reduces the quantum of installed power generation capacity required considerably.
- MSR doesn't need much space for installation, allowing for more flexibility in application and installation.
- MSR generates both heat and electricity and thus it eliminates the need for separate thermal energy input.

Unconventional hydrogen production methodologies ➤

Alkaline Electrolyser is the most common type of electrolyzer currently. This is mainly because it is cheaper than the other types of electrolyzers such as Proton Exchange Membrane (PEM) and Solid Oxide Electrolysis Cell (SOEC).

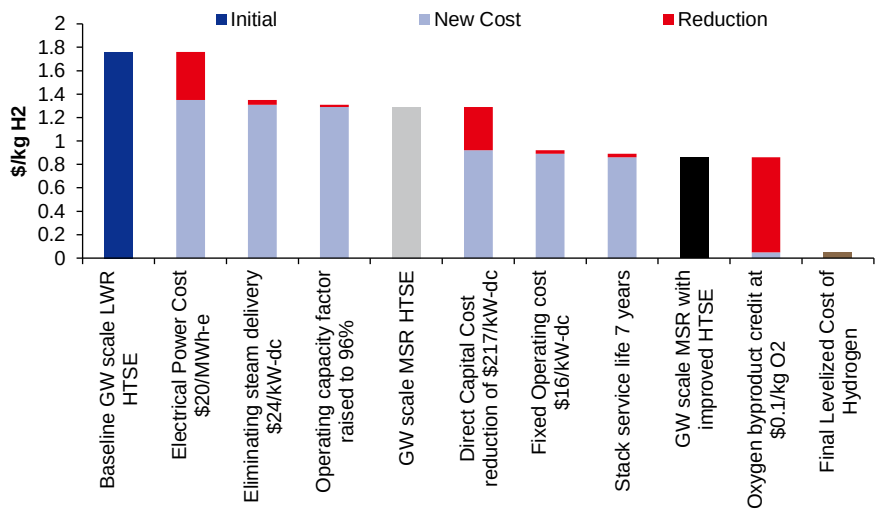
However, Alkaline Electrolyzer has a low efficiency of only about 55%. This means it needs approximately 72KWh of electrical energy input to make 1kg of hydrogen. In comparison, PEM electrolyzer has an efficiency of about 80% but is more expensive than an alkaline one. SOEC will be the most efficient one at 90-95%, but it operates at a high temperature (>600^{o}C). SOEC can enable High Temperature Steam Electrolysis (HTSE), which currently has an efficiency of 90.2% and is estimated to reach 95% by the end of the decade with simultaneous improvement in its durability and economics.

Thus, an MSR coupled to HTSE system in a cogeneration plant would be the most optimal system, given current technology-readiness levels.

MSR-HTSE cogeneration plant ➤

We have tried to estimate the levelized cost of hydrogen production using MSR and HTSE systems. This is based on a study by the US-based Idaho National Laboratory. Indirect capital costs like land, contractor fees, etc. are excluded to allow for easier internationalization of this cost model.

Figure 1: The path beyond US$2/kg cost for hydrogen production



SOURCE: IDAHO NATIONAL LAB, INCRED RESEARCH, COMPANY REPORTS

We start at a baseline 1GW electric capacity Light Water Reactor (LWR), the most common type of commercial nuclear reactor available currently. The HTSE system is assumed to be located outside the boundary of the nuclear power plant, necessitating a 1km steam delivery system to provide thermal energy for the HTSE.

Upon changing the reactor to MSR, we obtain electricity cost reduction from US$30/MWh-e to US$20/MWh-e. We also collocate the MSR with the HTSE, obviating the need for a 1km-long steam delivery system. Another factor is the availability of the power source. MSR can easily manage capacity factor of 95-100%.

Now, let's look at the improvement in HTSE performance and economics. Firstly, we expect economies of scale to bring down the unit cost of a HTSE plant by US$217/kW-DC. This is 50% of the current direct capital cost. This also halves the cost of replacing the electrolyzer, leading to a reduction in fixed operating cost by US$16/kW-DC. Next, the baseline service life estimation of the electrolyzer stack service is four years as it degrades very quickly. A rise in service life to seven years further reduces the cost to maintain plant capacity and production.

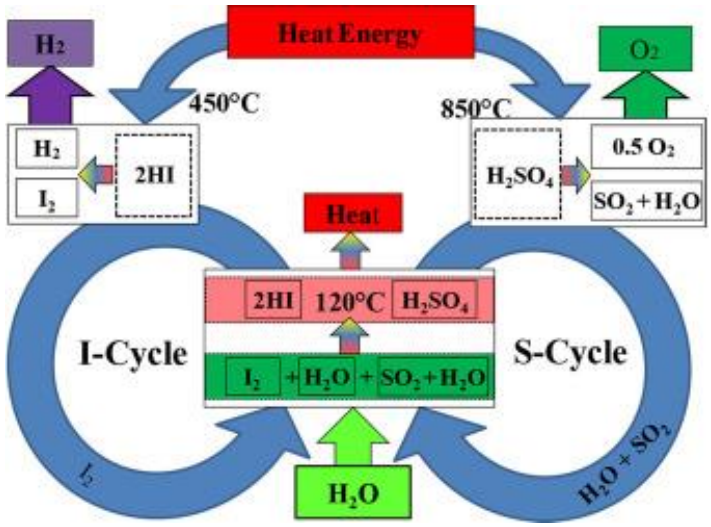
Finally, we also believe that the HTSE plant will generate revenue through the sale of oxygen. For every kg of hydrogen produced, 8.1kg of high purity oxygen would also be produced. In 2019, high purity oxygen was sold for US$3/kg. We have very conservatively set the price for the oxygen by-product at US$0.1/kg, given the sizeable logistics cost in transporting it. Besides, at such a price level we would have a negative cost for our production of hydrogen itself! Thus, the identification and development of large markets for oxygen would greatly reduce hydrogen prices.

Further, HTSE will also generate waste heat of 100-150^{o}C and this could be sold as low-grade thermal energy. The most synergetic customer of such heat would be a sea water desalination plant. Thus, a triple cogeneration plant consisting of MSR, HTSE and desalination plant could be operated in a highly economical manner.

Further improvement in hydrogen production methodologies

Currently, there is considerable research going on to make thermochemical cycles-viable hydrogen production methodologies. These cycles obtain most of their energy input in the form of heat, and not electricity. This significantly reduces their energy cost. Also, the devices which carry out these thermochemical reactions would have a much longer service life than electrolyzers. To cite an example, electrolyzers have an operational life of not more than 15 years whereas these devices would be like the ones used in chemical production, processing plants currently and hence, can have an operational life of 20-30 years.

Figure 2: Sulphur-iodine thermochemical cycle



SOURCE: INCRED RESEARCH, COMPANY REPORTS

The chart above illustrates the sulphur-iodine thermochemical cycle which can be used to crack water with the help of high temperatures. Interestingly, this cycle also generates heat at approximately 120°C, which could be used as thermal energy input in a sea water desalination plant.

Ammonia production

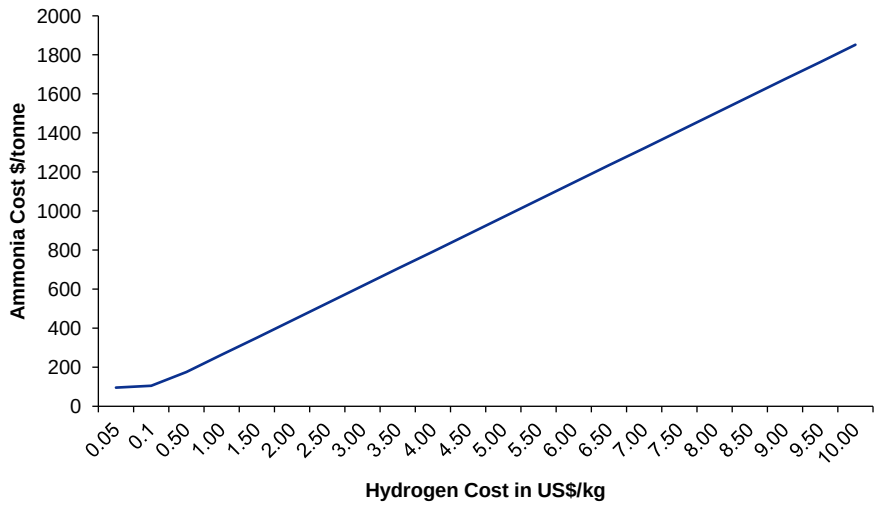
Ammonia is a key chemical for the chemicals and fertilizer industry which requires a sizeable quantity of hydrogen

As mentioned in our earlier report on green hydrogen (High LNG prices = green hydrogen viable), rising natural gas prices will help drive significant demand for alternative methodologies of hydrogen production, especially renewables and nuclear power-driven hydrogen.

Meanwhile, ammonia is shaping up to be a highly promising alternative marine fuel, at least in the short term. Please see our earlier report on the subject: (Ammonia and methanol as marine fuels). This is expected to raise ammonia demand significantly.

We have built a cost model for ammonia production which foregoes traditional feedstock and fuel but obtains both these energy inputs indirectly from an MSR. This plant obtains energy as a service from the MSR operator, and also obtains hydrogen as a product from an MSR-driven HTSE plant.

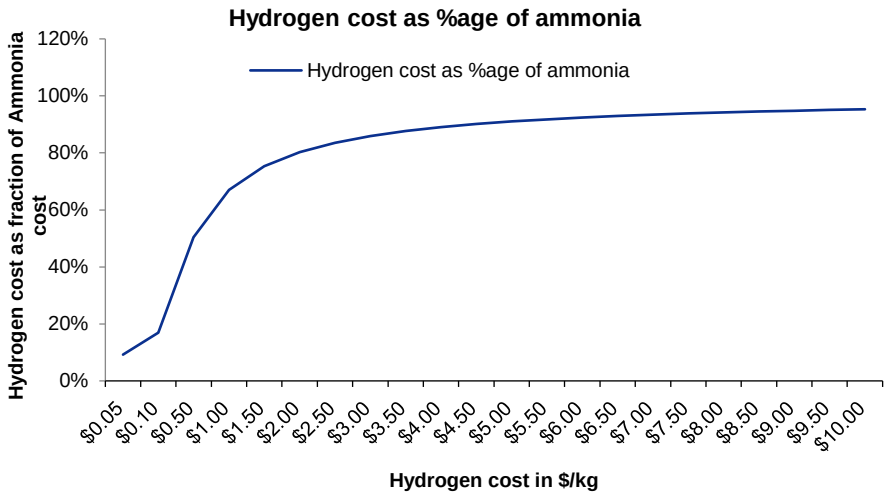
Figure 3: Variation in ammonia cost by hydrogen cost



SOURCE: LUCIDCATALYST.COM, INCRED RESEARCH, COMPANY REPORTS

At approximately US$1/kg hydrogen cost, we obtain ammonia cost of US$263/t. This is highly competitive, given the current ammonia prices.

Figure 4: Variation in hydrogen's contribution to ammonia cost by nominal hydrogen cost

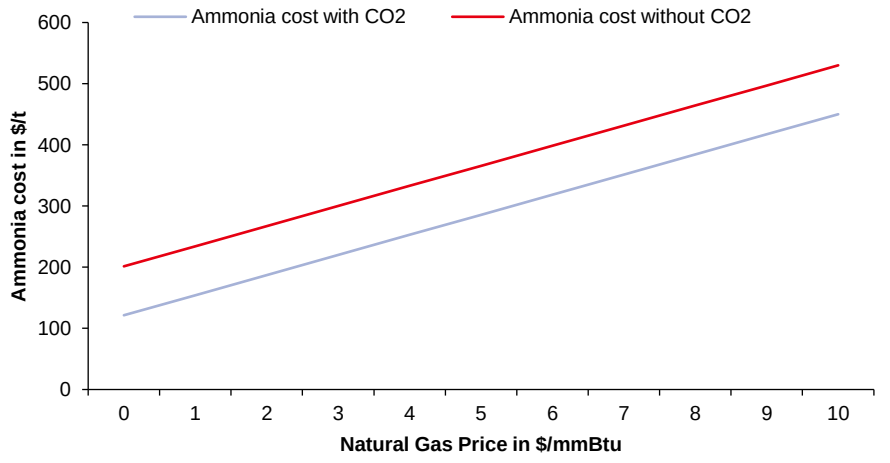


SOURCE:LUCIDCATALYST.COM, INCRED RESEARCH, COMPANY REPORTS

Traditionally, hydrogen cost has been the main driver of ammonia cost. But as we go below hydrogen cost of US$1/kg, hydrogen's contribution to ammonia falls 60%. Below US$0.5/kg H2, thermal energy cost starts driving the cost of production for ammonia.

Comparison with ammonia production from natural gas

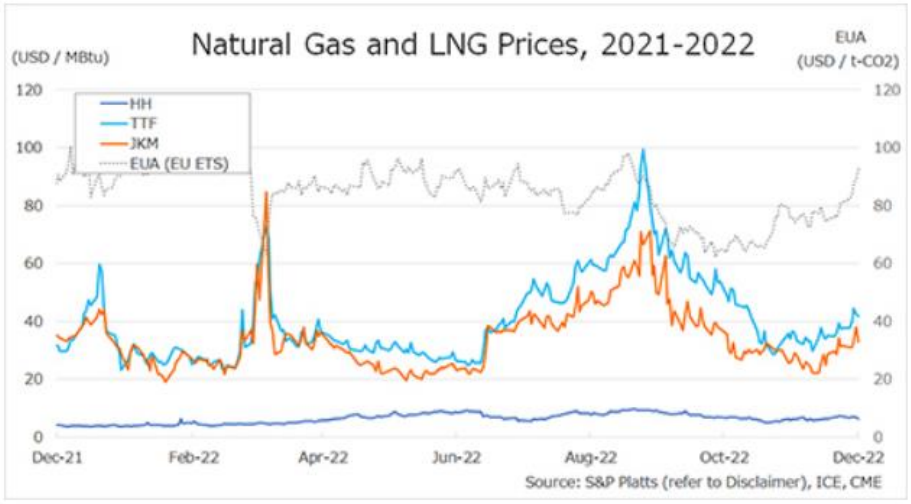
Figure 5: Ammonia production cost from steam methane reforming of natural gas as a function of natural gas cost



CARBON CAPTURE AND SEQUESTRATION (CCS) COSTS ABOUT $80/TON OF AMMONIA
SOURCE: AMMONIAENERGY.COM, INCRED RESEARCH, COMPANY REPORTS

The chart above shows the variation in ammonia cost as a function of natural gas cost. At US$1/kg hydrogen price, natural gas price must fall below US$4/mmBtu for ammonia production without carbon capture and sequestration (CCS). But with CCS, natural gas price must fall below US$2/mmBtu to be economically competitive with MSR-based production of hydrogen and ammonia.

Figure 6: Natural gas prices globally



Even Henry Hub prices aren't low enough to compete with MSRs

SOURCE: GOOGLE, INCRED RESEARCH, COMPANY REPORTS

As the chart above indicates, even Henry Hub's low natural gas prices wouldn't be low enough to compete with MSR-driven ammonia production. Add to this, the steadily rising natural gas demand alongside geopolitical tensions hurting supply, and we can see why MSR-driven hydrogen production will become extremely attractive to onsite hydrogen consumers like the chemicals industry.

DISCLAIMER

This report (including the views and opinions expressed therein, and the information comprised therein) has been prepared by Incred Research Services Private Ltd.(formerly known as Earnest Innovation Partners Private Limited) (hereinafter referred to as "IRSPL"). IRSPL is registered with SEBI as a Research Analyst vide Registration No. INH000007793. Pursuant to a trademark agreement, IRSPL has adopted "Incred Equities" as its trademark for use in this report.

The term "IRSPL" shall, unless the context otherwise requires, mean IRSPL and its affiliates, subsidiaries and related companies. This report is not directed or intended for distribution to or use by any person or entity resident in a state, country or any jurisdiction, where such distribution, publication, availability or use would be contrary to law, regulation or which would subject IRSPL and its affiliates/group companies to registration or licensing requirements within such jurisdictions.

This report is being supplied to you strictly on the basis that it will remain confidential. No part of this report may be (i) copied, photocopied, duplicated, stored or reproduced in any form by any means; or (ii) redistributed or passed on, directly or indirectly, to any other person in whole or in part, for any purpose without the prior written consent of IRSPL.

The information contained in this report is prepared from data believed to be correct and reliable at the time of issue of this report.

IRSPL is not required to issue regular reports on the subject matter of this report at any frequency and it may cease to do so or change the periodicity of reports at any time. IRSPL is not under any obligation to update this report in the event of a material change to the information contained in this report. IRSPL has not any and will not accept any, obligation to (i) check or ensure that the contents of this report remain current, reliable or relevant; (ii) ensure that the content of this report constitutes all the information a prospective investor may require; (iii) ensure the adequacy, accuracy, completeness, reliability or fairness of any views, opinions and information, and accordingly, IRSPL and its affiliates/group companies (and their respective directors, associates, connected persons and/or employees) shall not be liable in any manner whatsoever for any consequences (including but not limited to any direct, indirect or consequential losses, loss of profits and damages) of any reliance thereon or usage thereof.

Unless otherwise specified, this report is based upon reasonable sources. Such sources will, unless otherwise specified, for market data, be market data and prices available from the main stock exchange or market where the relevant security is listed, or, where appropriate, any other market. Information on the accounts and business of company(ies) will generally be based on published statements of the company(ies), information disseminated by regulatory information services, other publicly available information and information resulting from our research. Whilst every effort is made to ensure that statements of facts made in this report are accurate, all estimates, projections, forecasts, expressions of opinion and other subjective judgments contained in this report are based on assumptions considered to be reasonable as of the date of the document in which they are contained and must not be construed as a representation that the matters referred to therein will occur. Past performance is not a reliable indicator of future performance. The value of investments may go down as well as up and those investing may, depending on the investments in question, lose more than the initial investment. No report shall constitute an offer or an invitation by or on behalf of IRSPL and its affiliates/group companies to any person to buy or sell any investments.

The opinions expressed are based on information which are believed to be accurate and complete and obtained through reliable public or other non-confidential sources at the time made. (Information barriers and other arrangements may be established where necessary to prevent conflicts of interests arising. However, the analyst(s) may receive compensation that is based on his/their coverage of company(ies) in the performance of his/their duties or the performance of his/their recommendations. In reviewing this report, an investor should be aware that any or all of the foregoing, among other things, may give rise to real or potential conflicts of interest. Additional information is, subject to the duties of confidentiality, available on request.

The report is not a "prospectus" as defined under Indian Law, including the Companies Act, 2013, and is not, and shall not be, approved by, or filed or registered with, any Indian regulator, including any Registrar of Companies in India, SEBI, any Indian stock exchange, or the Reserve Bank of India. No offer, or invitation to offer, or solicitation of subscription with respect to any such securities listed or proposed to be listed in India is being made, or intended to be made, to the public, or to any member or section of the public in India, through or pursuant to this report.

The research analysts, strategists or economists principally responsible for the preparation of this research report are segregated from the other activities of IRSPL. Information barriers and other arrangements have been established, as required, to prevent any conflicts of interests.

The research analysts, strategists or economists principally responsible for the preparation of this research report are segregated from the other activities of IRSPL. Information barriers and other arrangements have been established, as required, to prevent any conflicts of interests.

IRSPL may have issued other reports (based on technical analysis, event specific, short term views etc.) that are inconsistent with and reach different conclusion from the information presented in this report.

Holding of Analysts/Relatives of Analysts, IRSPL and Associates of IRSPL in the covered securities, as on the date of publishing of this report

	Analyst/ Relative	Entity/ Associates
any financial interests in the company covered in this report (subject company) and nature of such financial interest	NO	NO
actual/beneficial ownership of 1% or more in securities of the subject company at the end of the month immediately preceding the date of publication of the research report or date of the public appearance;	NO	NO
any other material conflict of interest at the time of publication of the research report or at the time of public appearance	NO	NO
received any compensation from the subject company in the past twelve months for investment banking or merchant banking or brokerage services or investment advisory or depository or distribution from the subject company in the last twelve months for products/services other than investment banking or merchant banking or broker- age services or investment advisory or depository or distribution from the subject company in the last twelve months	NO	NO
managed or co-managed public offering of securities for the subject company in the last twelve months	NO	NO
received any compensation or other benefits from the subject company or third party in connection with the research report	NO	NO
served as an officer, director or employee of the subject company	NO	NO
been engaged in market making activity for the subject company	NO	NO

Analyst declaration

- The analyst responsible for the production of this report hereby certifies that the views expressed herein accurately and exclusively reflect his or her personal views and opinions about any and all of the issuers or securities analysed in this report and were prepared independently and autonomously in an unbiased manner.
- No part of the compensation of the analyst(s) was, is, or will be directly or indirectly related to the inclusion of specific recommendations(s) or view(s) in this report or based any specific investment banking transaction.
- The analyst(s) has(have) not had any serious disciplinary action taken against him/her(them).
- The analyst, strategist, or economist does not have any material conflict of interest at the time of publication of this report.
- The analyst(s) has(have) received compensation based upon various factors, including quality, accuracy and value of research, overall firm performance, client feedback and competitive factors.

IRSPL and/or its affiliates and/or its Directors/employees may own or have positions in securities of the company(ies) covered in this report or any securities related thereto and may from time to time add to or dispose of, or may be materially interested in, any such securities.

IRSPL and/or its affiliates and/or its Directors/employees may do and seek to do business with the company(ies) covered in this research report and may from time to time (a) buy/sell the securities covered in this report, from time to time and/or (b) act as market maker or have assumed an underwriting commitment in securities of such company(ies), and/or (c) may sell them to or buy them from customers on a principal basis and/or (d) may also perform or seek to perform significant investment banking, advisory, underwriting or placement services for or relating to such company(ies) and/or (e) solicit such investment, advisory or other services from any entity mentioned in thisreport and/or (f) act as a lender/borrower to such company and may earn brokerage or other compensation. However, Analysts are forbidden to acquire, on their own account or hold securities (physical or uncertificated, including derivatives) of companies in respect of which they are compiling and producing financial recommendations or in the result of which they play a key part.