ACN 109 200 900

AUSTRALIAN SECURITIES EXCHANGE ANNOUNCEMENT

12 August 2014

Carbon Nanotube-Enriched Concrete -Project Review

Background

- **Carbon Nanotubes (CNT)** (**see Figures 1 and 2**) are super strength, highly conductive (thermal and electrical) nano-carbon particles with a flexural strength of 200-300 times stronger than steel. Their discovery, along with other related forms of carbon such as "Bucky Balls" and more recently graphene, has occurred over the past 25 years, and all these forms of carbon, with a range of unique properties have been and continue to be the subject a vast amount of global research.

Figure 1- Eden's Carbon Nanotubes

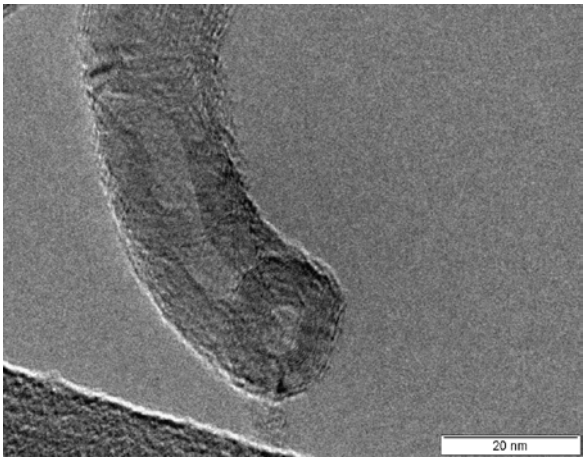


Figure 2 TEM Image of Eden's Multi-Walled CNT

- **Starting in late 2005, Eden developed with University of Queensland** (UQ) a low cost pyrolysis technology to produce CNT and hydrogen (H_2) from methane (CH_4) without producing any carbon dioxide (CO_2) as a by-product of the process (the Technology).
- **Hythane Company, based in Denver**, Colorado, Eden's wholly owned US subsidiary, is a specialist hydrogen company with a range of technologies and patents related to using hydrogen as a highly efficient, ultra-clean fuel, both as pure hydrogen and in a mixture of natural gas and hydrogen (Hythane^{TM}).
- **Eden's objective was to develop a low cost method of producing** hydrogen and solid carbon, without producing any carbon dioxide. However, when the solid carbon was identified as carbon nanotubes, Eden then expanded to focus on the potential value and opportunities that the carbon nanotubes offered.
- **In 2011 Eden acquired the Technology from UQ** and it is now 100% owned by Eden.

Level 15, 197 St Georges Terrace, Perth, Western Australia 6000
Telephone: (08) 9282 5889 Facsimile: (08) 9282 5866
Email: mailroom@edenenergy.com.au

- **Hythane Co was assigned responsibility for the commercialisation** of the Technology. A new method of producing a low cost, efficient catalyst was developed by Hythane Co. It also refined the production process to its current modular, continuous or batched production design capable of producing large quantities of CNT and hydrogen without producing CO_2 (**see Figure 3**)

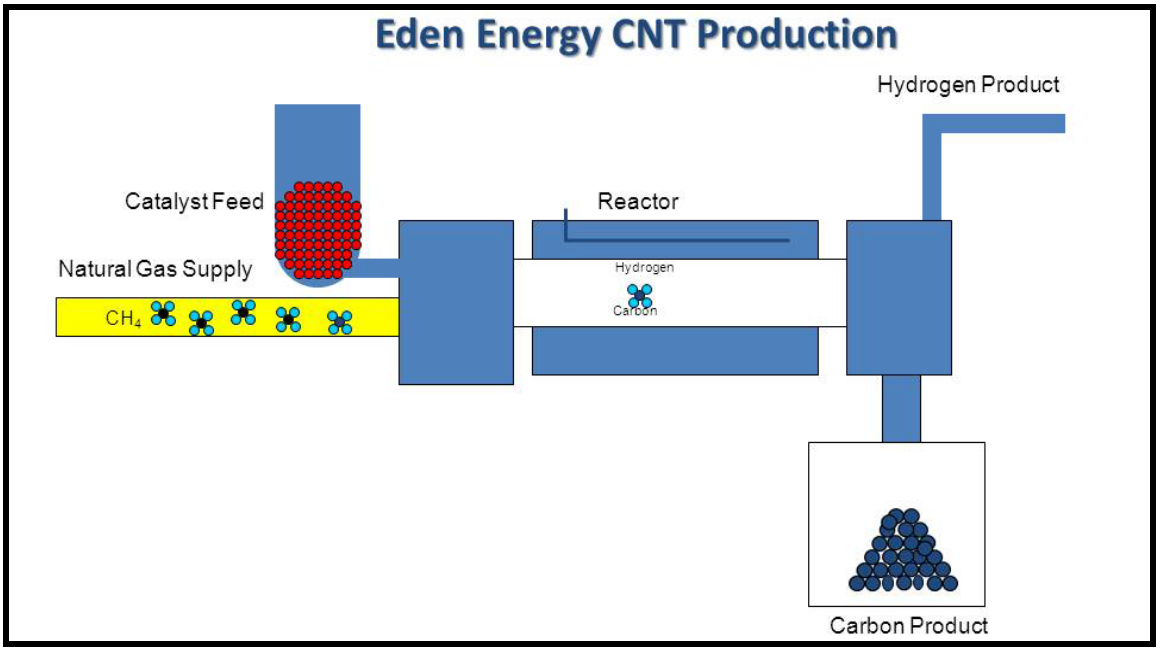


Figure 3 Eden's Carbon Nanotube Production Process

- **Hythane Co also up-scaled and expanded the production** capacity to its current commercial scale CNT production capacity (40 tonnes pa of CNT) (see **Figure 4**).

Figure 4 Eden's Denver-based CNT Production Clean Room and Reactors

- **Eden's believes that CNT enriched concrete** will be the initial bulk market application for its CNT followed by CNT enriched plastics/polymers for future bulk commercial applications.

Advantages of CNT enriched concrete

- **The extreme strength and lightness of CNT** make them unique as potential additives for concrete. A small weight percentage of CNT added to concrete greatly increases both compressive and flexural strength, reducing the amount of material required, and extending the range of possible applications whilst also reducing the aggregate costs.
- **Competitive concrete additives**, such as high performance fibre reinforced concrete, fly-ash and blast furnace slag, increase the flexural strength of concrete but:
  - Require significantly greater quantities of additives and finer crushed aggregates. ;
  - Generally do not increase compressive strength (necessary for abrasion resistance).
  - CNT can be used in far lower concentrations than other competitive products because of their phenomenal strength; extremely low mass and the nucleation effect for cement hydration that they create (**see Figure 5**). Being stronger and lighter, less concrete is required and the building time and energy consumption are greatly reduced, both factors of significant relevance to the cost of construction.

Progress to Date

- **CNT clump together**, and in order to add them to concrete or polymers to increase its strength, a technique is needed to avoid this agglomeration. Eden, as well as three of its research partners have identified suitable methods for this for both concrete and plastics/polymers markets.
- **Monash University, with which Eden has been collaborating** for over two years (and proposes to continue collaborating with in the future) in relation to development of CNT enhanced concrete, developed a suitable liquid surfactant which it mixed with Eden's CNT in a trial with CNT enriched .cement paste and achieved an increase in compressive strength of up to 30%.
- **Monash University analysed the** CNT enriched .cement paste in Singapore and captured Helium Ion Microscope images of the CNT in the cement paste that showed:
  - In fresh cement paste, CNT act as nucleation points for cement hydration - rather than acting solely as nano-scale fibre reinforcement (like larger-scale fibres). CNT beneficially alter the microstructural development (and thus the pore structure) of cement (OPC)-CNT mixtures by nucleating the formation of a denser microstructure, resulting in a stronger and potentially more durable composite. **(see Figure. 5),** .and
  - Within hardened cement paste (viewed after being intentionally fractured) the ends of the CNT are well bonded in the cement gel providing anchorage for the CNT **(see Figure. 6)**.

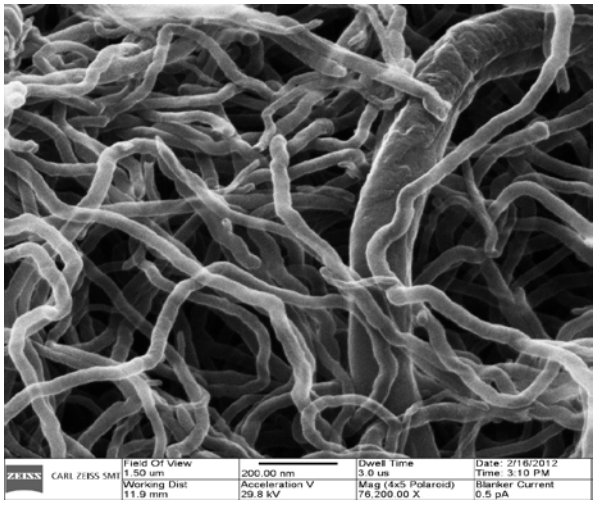


Figure 5 Helium Ion Microscope Image of Eden's Carbon Nanotubes in Fresh Cement Paste (showing build-up of dense hydrated cement on the surface of the CNT (top right) due to CNT acting as nucleating points for cement hydration)

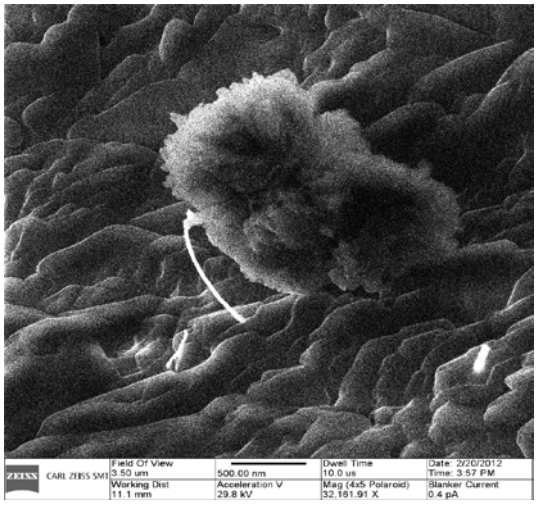


Figure 6 Helium Ion Microscope Image of Eden's Carbon Nanotubes in Hardened Cement Paste after Fracturing (showing that the ends of the CNT are well-bonded within the cement gel and provide anchorage)

- **Hythane Co**, on its own account, and secondly in conjunction with a US concrete consultant has also developed suitable liquid surfactants mixed with Eden's CNT to strengthen concrete. Both of these have been mixed with and tested in a cement paste comprising 0.5% (by weight) of CNT : 99.5% (by weight) of cement and produced increases in compressive strength in the cement paste of up to 23.3% and a 13.6% increase in flexural strength after 28 days

The Product and Target Markets

- **The product that Eden proposes to sell will be its CNT**, for adding to suitable liquid surfactants, creating commercial admixtures that will be added to concrete during production in the same manner that other admixtures are presently introduced, to produce stronger concrete.
- **Eden proposes to test the CNT enriched concrete** over the next 12-24 months in USA and Australia, prove up the markets and then licence suitable admixture manufacturers to produce Eden's Admixture using Eden's CNTs for marketing to a global market.
- **Concrete is the most widely used man-made product in the world**. Approximately a ton of concrete is produced every year for each person on the planet. USA uses in excess of 700 million tonnes annually. Additionally, cement production accounts for 5% of annual anthropogenic Greenhouse Gas Emissions (**GHG**). The 2012 global concrete and cement market was reported to have been worth US$449 billion, with cement sales comprising 43.2%, followed by ready-mix concrete.
- **The initial target applications for Eden's CNT enriched concrete** are high abrasion resistant applications followed by high strength for high rise applications. Road and bridges in areas that are subject to heavy snowfall and where snow ploughs are used to clear the roads, suffer severe abrasion and damage to the road surfaces requiring frequent repairs. USA has some 89,000kms of concrete paved roads and bridges, and a US $40billion annual infrastructure maintenance cost.
- **The ratio of CNTs to cement required** (0.5% by weight of CNT: 99.5% by weight of cement is equivalent to only 600g- 900g of CNTs per tonne of concrete mixtures.
- **Eden's existing reactors are capable of producing 40tonnes/yr. of CNT and will supply initial demand**. Although larger reactors will be required, these units are relatively cheap due to the simplicity of their design. Eden budgets being able to fund the initial additional reactors from anticipated revenue from CNTs and OptiBlend™ sales.
- **Hythane Co will expand commercial scale production** of the CNTs as required.
- **The capital cost of reactors is calculated to fall per unit of CNT production** as the capacity increases. When large scale production is required the business will be well proven and conventional funding available. A 1000 tonnes/year reactor would be sufficient to enrich 1.7 million tonnes of concrete.
- **Future large scale production of Eden's CNT** is planned at natural gas fired power stations (or fertiliser plants which produce H_2 from CH_4 to make ammonia), using the incoming natural gas as feedstock, with the H_2 by-product being re-mixed into the natural gas that is used for the turbine fuel, reducing both the cost of the power (subsidised by the value of CNT produced) and the level of Greenhouse Gas Emissions (**GHG**) produced by the power station.
- **An efficient (60%) 500MW combined cycle gas fired power station consumes over 100,000 tonnes p.a. of natural gas**. A 10,000 tonnes p.a. capacity CNT reactor installed at such a power station would consume less than 10% of the power station's total gas supply, producing sufficient CNT for 17 million tonnes of concrete - a small fraction of the annual US highways maintenance needs, whilst also saving the power station 36,666 tonnes p.a. of GHG emissions.

- **Eden will be a very low cost manufacturer of CNTs due to:**
  - -A proprietary low cost catalyst developed by Eden (no noble metals), plus a low cost feedstock (CH_4);
  - -The low cost, continuous or batched production process (**see Figure 3**);
  - -The H_2 by-product (calorific value of 141,790kJ/kg), equal to 25% by mass of the CH_4 used to produce the CNT, will be fed back into the CH_4 fuel supply (calorific value of 55,530kJ/kg) for the reactor, or into the turbine fuel if the CNT are produced at a power station, capturing the energy potential of the H_2 by-product (being equivalent to approx. 64% of the energy of the CH_4 used to make the CNT).
  - Any future value of Greenhouse Gas emissions reductions (from removing the carbon and using the hydrogen) will be available to further reduce the effective production cost of the CNT.

Market Challenges

- **The primary unresolved technical issue** for the CNT-concrete application is extending the shelf life of Eden's Admixture from 3 months to 6-12 months. Whilst the current shelf life is not considered to be a project stopping issue, it will require far tighter management of the distribution chain. However, Eden's US concrete consultant is confident that a suitable solution will be found.

- **Testing and Certification of CNT enriched Concrete -** For most applications, long term testing of the CNT- enriched concrete against international standards will be necessary. This testing is planned to be conducted in USA in conjunction with Eden's concrete consultant over the next 12-24 months. Eden is confident that the concrete will meet the various required standards and if so, it will then be possible to supply Eden's Admixture for a range of applications that require concrete that meets these approved standards. In the meantime commercial trials of the CNT enriched concrete will be undertaken on hardened surfaces such as road surfaces, which do not carry the same risks as concrete used in high rise construction.

- **Occupational Health and Safety-** CNT, similar to asbestos fibres, are many times longer than they are wide. This has caused concern that if inhaled, CNT may cause lung and respiratory problems like asbestos and appropriate standards have been set in many countries.
  Eden has constructed a sealed clean room with its own air supply to house the production reactors and otherwise meets the maximum US recommended specifications for safe working conditions which all workers follow strictly (**see Figure 4**).
  In 2012, Safe Work Australia and CSIRO recommended that CNT be kept in solution and embedded in a suitable matrix. Additionally, a product containing CNT must carry a warning if it contains more than 10% CNT. Eden's proposed admixture, in which the CNT are mixed in a liquid surfactant, has a concentration of less than 1% CNT Similarly in concrete, the CNT are firmly bonded with the cement in significantly less than a 1% concentration.

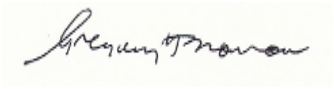
Planned Future Activities

- **Field trials of CNT-enriched concrete** targeting abrasion resistant applications are planned to be conducted in USA over the next 12-24 months to extend the initial results from cement paste to concrete and to validate the increased strength and suitability for production of abrasion resistant concrete and then for other applications such as high-rise construction.

- **Further work is required** to extend the usable shelf- life of Eden's Admixture from its present 3 months (before the CNT start to drop out of the solution) to 6-12 months. Eden's US concrete consultant is confident that this will be successful. The current shelf life of Eden's Admixture is commercially viable, but would require far tighter controlled marketing and distribution procedures to ensure use within 3 months of production.

- **Initial discussions are underway with a major concrete company** in relation to undertaking collaborative research and possible Australian trials of CNT enriched concrete.

- **Ongoing research with Monash University is proposed** targeting high strength CNT enriched concrete requiring little or even no reinforcing steel. This potentially offers far more flexible designs, a wider range of applications (particularly in areas such as seawalls and other marine structures which are subject to significant risk of concrete breakdown due to corrosion of the reinforcing steel), and significantly lower building costs. A far lower Greenhouse Gas footprint would be an additional point of significant advantage for CNT enriched concrete.
- **Additional research opportunities** exist for optimising the recycling potential of the CNT enhanced concrete and developing technologies for crushing the strengthened concrete for use as a very hard aggregate suitable for use in future ultra-high strength concrete applications.
- **After completion of the trials in USA and Australia** over the next 12-24 months, Eden will review the alternative methods of building up its manufacturing and marketing base so it can progressively expand its sales into the huge global concrete market. The likely model for managing the admixture production and marketing is to seek to licence suitable manufacturers of concrete admixtures to manufacture the CNT enriched admixture using Eden's CNT, and market it to the global market.



Gregory H. Solomon
Executive Chairman