B9 SHIPS: SAIL AND VIRTUAL BIO-METHANE POWERED COASTAL VESSELS

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ABSTRACT

The renewable fuel industries which include biomass and bio-liquids are among the first to demand that use of fossil bunker fuels at sea is reduced to zero in order to retain the environmental performance of their carbon neutral products such as green electricity. B9 shipping Ltd is developing the design of a 3,000 dwt coastal sailing vessel that is fitted with a spark ignition main engine designed to burn bio-methane. About 60% of the thrust will come from soft sails utilising the offshore wind resource (zero carbon emissions) and 40% will come from the engine (carbon neutral). The free standing and free rotating Dyna-rig system, originally designed in the 1960's by Wilhelm Prolls, has been chosen as the sailing rig and the biogas will be produced by the anaerobic digestion of food waste and other commercial and industrial organic waste streams. The biogas is processed to give bio-methane and when this is liquefied it exhibits all the characteristics of LNG so that off the shelf equipment for storage and handling of LNG can be used. For the first time, the new Renewable Energy Directive 2009/28/EC, requires member states to promote the use of renewable energy in all forms of transport, not just road vehicles i.e. the requirements have been extended to ships, trains and aircraft. To this end B9 ships provide the marine surface transport sector with an innovative combination of wind and biogas. Indeed, the directive allows biogas to make a double contribution to compliance with renewable energy obligations and national targets. The B9 ship, therefore, has the ability to capture many of the key novel intentions of the Renewable Energy Directive.

Keywords: sail, virtual, bio-methane, coastal vessels

NOMENCLATURE

AD	Anaerobic Digestion
B9	Company name meaning "Benign"
CHP	Combined Heat and Power
Dwt	Deadweight tonnes – the weight of cargo being carried by the ship
GHG	Greenhouse Gas
IEA	International Energy Agency
ISO	International Standards Organisation
kWhr	Kilo-watt-hour
LNG	Liquid Natural Gas
MGO	Marine Gas Oil
RED	Renewable Energy Directive
ROC	Renewable Obligation Certificate

1. INTRODUCTION

B9 shipping Ltd is developing the design of a 3,000 dwt coastal sailing vessel that is fitted with a main engine running on bio-methane, see Figure 1. About 60% of the thrust will come from soft sails utilising the offshore wind resource (zero carbon emissions) and 40% will come from the engine (carbon neutral). The bio-methane will be produced by the anaerobic digestion of food waste and other commercial and industrial organic waste streams. B9 Organic Energy's grant supported 50,000 tonnes per annum AD project at Dungannon in Northern Ireland will serve to demonstrate this 2nd generation bio-fuel technology, see Figure 5.

The niche target market for B9 ships is to import large quantities of wood chips, wood pellets and bio-coal pellets into the UK to support the emerging biomass electricity generation and domestic heat sectors: (The IEA task 40 group estimates up to 45 million tonnes per annum will be needed to meet targets). The B9 ship has an economic range of 1,000 nautical miles so that the Baltic States are a top priority for sourcing biomass material, see Figure 1. Much larger Panamax sized ships operated by others will handle the trade from the Americas and Africa. The Environment Agency has indicated that emissions from transport are a potentially serious impediment to the environmental performance of the biomass industry and that this will have implications for gaining planning permission for new biomass power stations and for winning public and consumer support for carbon neutral electricity. The use of B9 ships would largely remove these concerns.

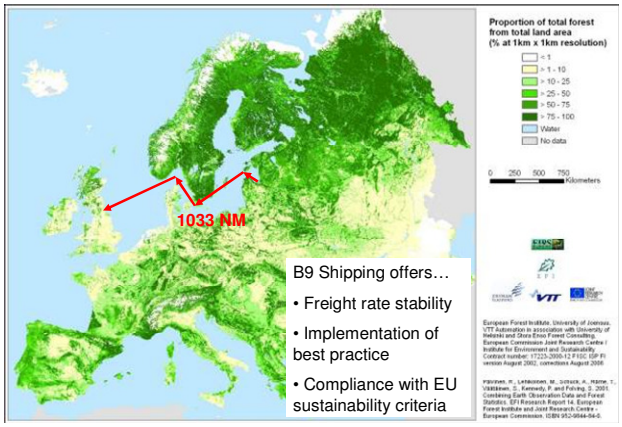


Figure 1: 1033NM route for biomass cargoes

2. BENEFITS

B9 ships will increase the use of renewable energy in transport – especially the very efficient use of 2nd generation biofuels. They will reduce dependence on imported oil, promote security of energy supply within the EU, stimulate innovation and technological development and provide opportunities for employment and regional development in merchant ship building and operation. In addition, because they are fossil fuel free and largely unaffected by the financial risk posed by peak oil, B9 ships will provide both long term price stability to the biomass industry and long term confidence to financial investors. Last, but not least, B9 ships will provide an instantly recognisable visual platform from which to raise awareness of renewable energy in action.

3. POWER FROM THE WIND

The free standing and free rotating Dyna-rig system, originally designed in the 1960's by Wilhelm Prolls, has been chosen as the sailing rig i) because it's automated operation reduces the number of crew required to similar levels that are seen on conventional coastal vessels, ii) allows modern health and safety regimes to be implemented with regard to working at heights, iii) because the lack of wires supporting the masts allows clutter free cargo handling operations and better upwind sailing performance due to the spars being free to rotate to finer angles.

It will also be possible to deploy a Skysails towing kite in order to maximise the benefits of wind power. The kite will be especially useful at high wind speeds when sail has to be shortened to limit heeling moments.

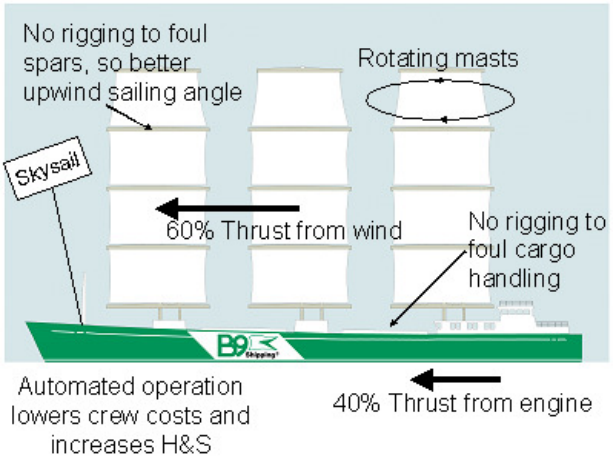


Figure 2.

The Dyna-rig has been deployed on a 3 masted super yacht called the Maltese Falcon and the operational experience has been very successful. Unlike traditional square rigged sailing ships the sails furl away inside the mast as the following picture shows…

Figure 3: In mast furling, with one of the crew inspecting the initial set-up. Photograph courtesy of Insensys.

Wind speeds in northern European waters are generally very high on average so that this is the best place to start operating a fleet of sailing cargo vessels. Figure 4 shows 10 years of historical wind data taken from a weather station near the Shetland Islands and plotted in such a way that each square represents the average wind speed during a 1 month period

10 Years of average monthly wind speeds

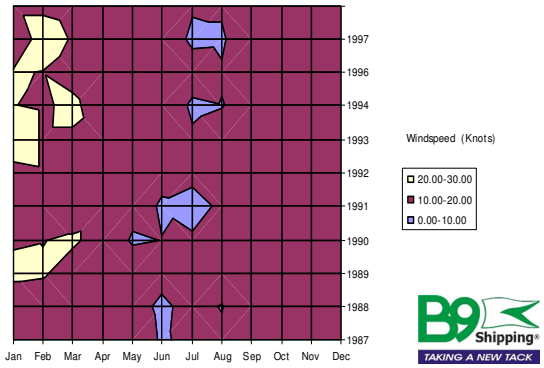


Figure 4: Shetland Island data

The blue patches in the summer months show the periods when there is generally too little wind to operate on wind alone so that it is necessary to motor and/or motor-sail. The yellow patches in the winter months, in contrast, show the periods when the wind is generally too strong for full sail to be

deployed and this is also when the vessel would be likely to shelter from storms and gales in the same way as conventional coasters. The burgundy coloured areas show the times of ideal sailing breezes although wind direction will have an influence on actual journey times and biogas consumption

1. POWER FROM FOOD WASTE

4.1 B9 ORGANIC ENERGY LTD

B9 Organic Energy Ltd is a member of the B9 Energy group of companies and specialised in development of energy projects which utilise the mature technology of Anaerobic Digestion, AD. This is a completely natural process that uses commonly occurring bacteria to "eat" organic material arising from industrial, commercial and residential waste streams, mostly food waste, to produce biogas consisting of 60% methane and 40% CO_2. The bacteria live in large tanks which are free of oxygen, hence "Anaerobic". The rival waste processing technology which uses "Aerobic" bacteria in air is called composting. This inferior process only gives CO_2 as an output so that the energy balance ends up being negative. Farm slurries and human sewage can also be anaerobically digested but the energy content per tonne of feedstock is much lower. B9 Organic Energy is approaching financial close on it's first 50,000 tonne per annum AD project at Dungannon in Northern Ireland. This project has been grant supported and will be generating electricity from the raw biogas using a spark ignition engine. Because the fuel for the engine is derived from organic waste and because, as a consequence the release of methane into the atmosphere from landfill sites has been avoided, it is described as a 2nd generation bio-fuel. Specific support is available for 2nd generation bio-fuels used in transport under the EU's Renewable Energy Directive as we shall see later.

Figure 5: Dungannon's 50,000 tonne per annum AD plant

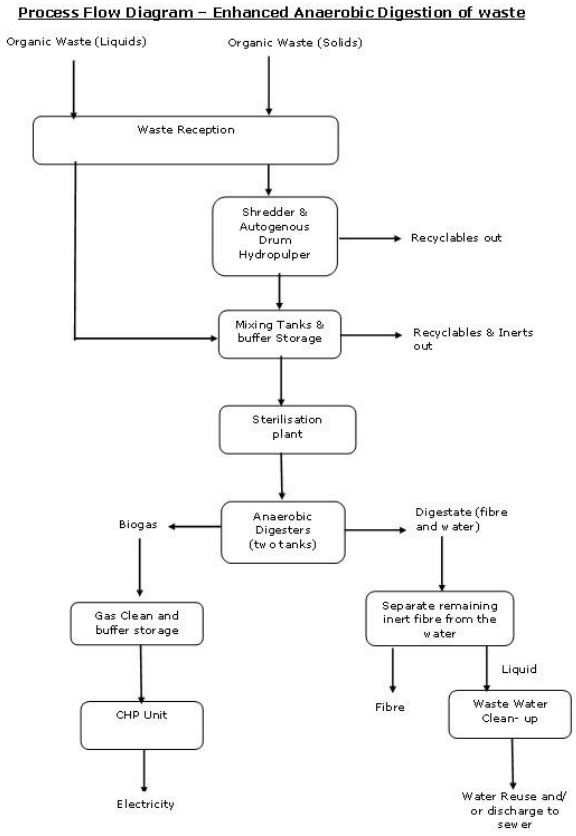


Figure 6: AD process diagram

4.2 BIOGAS UPGRADING

It would be possible to simply compress the raw biogas on site, transport it in road mobile tanks to B9 ships in port and then use it to fuel the B9 ship's spark ignition engines directly. To avoid having to compress for a second time the mobile tanks would be lifted onto the ship rather like a Calor gas bottle. However, the size of tanks required for storing enough fuel onboard to give the range and endurance required by flag and class requirements and good operating practice would be prohibitively large. We therefore need to upgrade the biogas at the AD plant by removing the 40% CO_2 so that only bio-methane remains. This biogas upgrading is achieved using pressurized water scrubbing technology which is readily available on the market.

Figure 8: Biogas upgrading plant

The next theoretical stage of the fuel gas supply chain is to liquefy the bio-methane gas so that it is 600 times denser than the bio-methane gas at atmospheric temperature and pressure. The equipment needed to carry out liquefaction down to the cryogenic temperature of minus 163 degrees C is available from the Liquid Natural Gas (LNG) industry because LNG has exactly the same physical and chemical properties as liquid bio-methane. However, in practice we intend to avoid the need to buy this equipment by purchasing LNG directly from an LNG importer and this assumes that arrangements for third party access to the natural gas network are sufficiently well advanced at that time.

4.3 THIRD PARTY ACCESS TO NATURAL GAS NETWORK

B9 Organic Energy will negotiate a gas purchase agreement with one of the main blue chip gas utilities in the UK to sell bio-methane from the AD plants. This will be a bankable 10 year contract that the AD plant investors and lenders will be comfortable with. Simultaneously B9 Shipping will negotiate a back to back LNG purchase agreement with an LNG importing company to buy the same quantity of gas on a kWhr basis as B9 Organic had fed into the grid. In this way B9 is able to use the natural gas network as a storage vector for its bio-methane and the utility makes money by charging a use of system charge. Rather than B9 shipping having to liquefy the gas, which is expensive on a small scale, it will be possible to take delivery of gas which is already in liquid form, i.e. from the LNG importing terminals. There are currently 3 of these terminals in the UK, one at the Isle of Grain and 2 at Milford Haven.

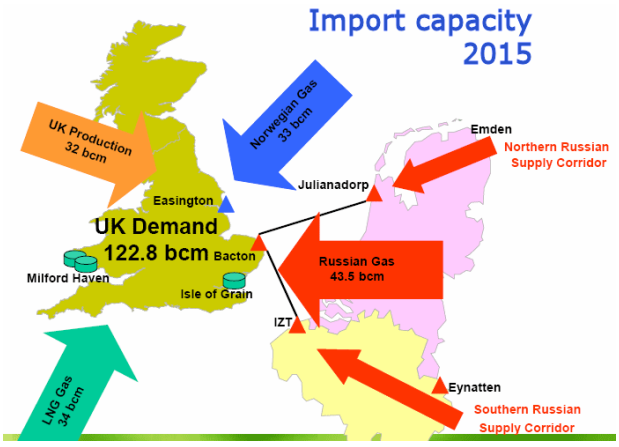


Figure 9: UK Natural Gas import including LNG

The LNG is imported on very large LNG tanker ships, stored onshore in liquid form and then evaporated using heat. The natural gas is then compressed into the national gas network for delivery to homes and businesses. When the LNG importer sells LNG to B9 Shipping it avoids the cost of evaporating the LNG and of compressing the natural gas into the network and these cost savings would be reflected in the contract value. Again this contract would be very bankable for B9 shipping's investors and lenders because the LNG could be supplied to the ships even if there was insufficient bio-methane being fed into the network. The environmental performance would drop during this period but the operational security of supply is maintained. Off the shelf equipment for transporting and handling LNG can be used without modification for moving LNG from the LNG terminals to the B9 ships in which ever port they are visiting and for performing shore to ship bunkering operations so that project capital costs can be kept reasonably low. We have called this whole solution the "Virtual Bio-Methane Supply Chain" and it can be summarised in the following diagram...

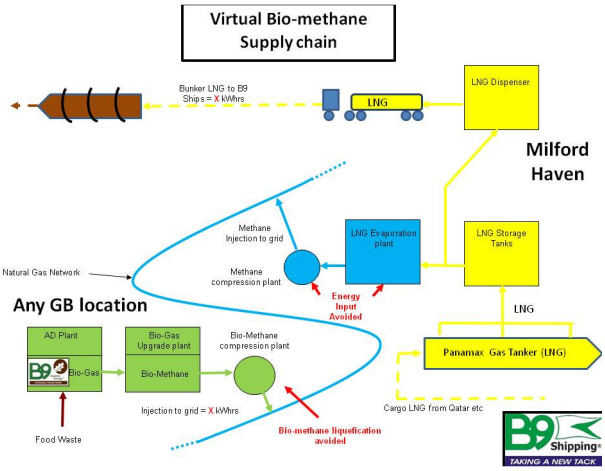


Figure 10: Virtual Bio-Methane Supply Chain

Figure 11: LNG road tanker.

The utilisation of LNG equipment also extends to onboard the ship. IMO type C cryogenic LNG storage tanks with a total capacity of 86m^3 have been specified and the evaporated natural gas will be fed to a 1.46 MW spark ignition main propulsion engine. B9 Shipping is working in conjunction with Rolls-Royce to utilise the Bergen gas engine series which has already been certified for use onboard ships. The following diagram shows the arrangement of an typical LNG engine room on a modern ferry.

Figure 12: Rolls-Royce Bergen gas engine arrangement

4.4 REFUELLING OUTSIDE THE UK

The carefully structured fuel gas supply chain within the UK allows the vessel to operate with no fossil fuel consumption and the onboard fuel tank size has been designed to be sufficient for a return trip to the Baltic States. However, in the event that it becomes necessary to refuel outside the UK then there are a number of suitable LNG bunker stations located along our route. The environmental performance would be diminished accordingly unless it became possible to buy bio-methane through the Swedish / Norwegian gas pipe networks. The following map shows the present LNG refuelling facilities that can be found along our route…

Figure 13: Some European LNG terminals

It should be remembered that the roll out of these stations has only recently begun as the Norwegians in particular recognise that LNG will be cost competitive with liquid distillate bunker fuels once the economic driver of peak oil kicks in. On the environmental side, the Emission Control Areas (ECAs) of the North Sea and the Baltic Sea will serve to increase demand for the distillates MDO and MGO so that refinery bottle necks will also result in higher prices. The respite provided by flue gas desulphurisation or "scrubbing" equipment for short will not suit all types of ship and the additional equipment costs will also be significant.

Figure 14: Environmental Control Areas

5. RENEWABLE ENERGY DIRECTIVE

For the first time, the new Renewable Energy Directive 2009/28/EC, which comes into force during 2010, requires member states to promote the use of renewable energy in all forms of transport, not just road vehicles i.e. the requirements have been extended to ships, trains and aircraft. The RED re-emphasises the importance of energy efficiency and highlights the need for biomass fuels to be sourced in a sustainable manner. Mandatory targets for energy from renewable sources are re-enforced to provide long term stability for the business community and "national renewable energy action plans" with their associated "economic support schemes" remain central tools for driving down carbon emissions. Member states are encouraged to diversify the mix of energy from renewable sources in all transport sectors. To this end B9 ships provide the marine surface transport sector with an innovative combination of wind and biogas. Indeed, Article 21 of the directive places a particular emphasis on 2nd generation biofuels allowing their use to make a double contribution to compliance with renewable energy obligations and national targets. The exact wording of Article 21.2 is as follows…

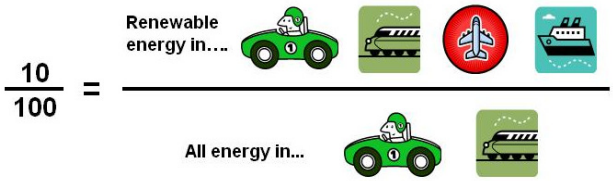
"For the purposes of demonstrating compliance with national renewable energy obligations placed on operators and the target for the use of energy from renewable sources in all forms of transport referred to in Article 3(4), the contribution made by biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material shall be considered to be twice that made by other biofuels."

The main purpose of this additional market support is to ensure that biofuel companies concentrate on using feedstocks from organic waste streams and non-food sources rather than relying on energy crops grown on farm land which is increasingly

needed for food production. A second purpose is to accelerate the diversion of organic wastes away from landfill sites so that this serious source of GHG emissions can be more rapidly reduced. The RED therefore supports the Landfill Directive which will ultimately ban all organic waste from being dumped in landfill sites.

Article 3(4) of the RED referred to above, which sets out that the share of energy from renewable sources in all forms of transport in 2020 is to be at least 10% of the final consumption of energy in transport, allows non road and rail consumption of biogas to make a disproportionately high contribution to the achievement of the target, i.e. biogas consumption in shipping only appears in the numerator and not the denominator of the calculation.

The following diagram serves to illustrate this…



These strong incentives to use biogas in shipping are not necessarily at variance with the automotive sector in the UK since we lack a well-developed infrastructure for gaseous road transport fuels.
Finally, a remarkable and perhaps unique implication in the case of wind assisted vessels including sailing ships is that the same disproportionately high contribution described above can also be claimed for wind power because Article 3.4b states that all types of energy from renewable sources consumed in all forms of transport shall be taken into account.
To conclude this section it is therefore safe to say that the B9 ship concept of deploying renewables in the non-road and rail sector, of utilising 2nd generation biogas, which avoids methane emissions from landfills, and of using the offshore wind resource to minimise the consumption of biogas has the ability to capture many of the key novel intentions of the Renewable Energy Directive.

6. NATIONAL ECONOMIC SUPPORT SCHEMES

In the same way that renewable energy in the UK electricity supply industry has been supported by the Renewables Obligation and renewable energy in the road transport sector has been supported by the Renewable Transport Fuel Obligation, it is essential that the marine transport sector also receives an appropriate level of support. A “Marine Renewables Obligation” would be fair if it provided the same level of support on a per kWhr basis as the more established renewable energy technologies. Renewable Energy Certificates or “ROCs” are currently trading at around 4.5p/kWhr and each renewable energy technology band has a different multiple of ROCs. Offshore wind has “double ROCs” thanks to the precedent set by the London Array project and so the sail power element of the B9 ship should also be double ROCs because both technologies are harvesting the same offshore wind resource. The 2nd generation biogas element of the B9 ship should likewise be “double ROCs” to be comparable with onshore AD biogas CHP generating stations. Indeed, if the shipping industry was to offer a lower ROC multiple than the electricity industry then a large part of the available biogas supplies would remain onshore. This would give rise to a rather perverse outcome on account of CHP’s end user environmental performance being generally inferior to that of ships. In other words the government would be incentivising a less efficient option. Assuming that the existing freight income for a coaster is in the region of $4,000 to $10,000 per sea day it becomes apparent that if both wind and biogas attract double marine ROCs then selling these ROCs would generate an income of about $6,000 per sea day and thereby transform the value proposition of these re-emerging and novel technologies. For comparison, carbon trading, even at predicted carbon values of 40 Euros per tonne, would only give a relative saving of $1,000 per sea day and fossil fuel cost savings, with MGO trading at $600/t, would amount to $3,000 per sea day less the $2,000 average daily cost of biogas, i.e. a saving of $1,000 per sea day.

7. CONCLUSION

In conclusion, the Renewable Energy Directive could ensure that national support schemes have sufficient value in them to incentivise the return of commercial sailing cargo ships and in return these vessels would provide significant contribution to meeting the new EU targets for renewable energy in transport

AUTHOR'S BIOGRAPHY

David Surplus holds the current position of Managing Director at B9 Shipping and Chairman of the B9 Energy group of companies. He is responsible for co-ordinating entrepreneurial efforts to realise a number of commercial projects that are compatible with the low carbon economy including the B9 Shipping project. His previous experience includes a degree in Marine Engineering from the University of Newcastle Upon Tyne, 2.5 years at sea as an engineering officer with Ropners from Darlington and 10 years with Lloyd's Register as an Engineer Surveyor in shipping and the offshore oil and gas industry. David is also founder of the B9 Energy group which is a successful pioneer of renewable energy development in the UK and Ireland market