WHEN THE OIL IS GONE: A FUTURE VISION FOR RAIL

By Jamie Keyte

1. Introduction:

To those who pay attention to such topics, it is clear that with unprecedented rates of consumption, dwindling reserves and increasing prices the days of petroleum fuelled transport are numbered. This article takes a speculative view of how the energy crisis might impact on the future of rail transport.

Firstly it is important to note that all that is written here regards the future. The author does not posses powers of foresight any better than the next person. This is simply one Engineer's view of how our future transport systems might evolve. It does not account of the unpredictable nature of the worlds financial situation, political upheaval, natural disaster, the inability of politicians (and the world at large) to see common sense and, of course, mankind's greed.

The picture painted in the following sections is based on the UK situation. There will be some parallels to other world transport systems, but the extent of the changes will depend on the local conditions.

2. When the Oil is Gone…

Various sources suggest that Peak Oil is past and that in about 20 years time oil reserves will have depleted to such an extent that demand (at today's levels) will far outstrip supply. As the majority of the worlds transport networks (in their current form) are *absolutely* dependent on oil there will clearly be some significant changes ahead.

It would seem likely that as reserves diminish governments will prioritize who, or what gets to use the oil. The Military, emergency services, food production, manufacture using oil as feedstock and other essential functions will take precedence over personal transport. Transport powered by internal combustion engines may simply become unviable due to the scarcity of fuel and its increasing cost.

It is also reasonable to predict that the way that society is organized will become very localized. This applies as much to the way individuals lead their lives as the production of goods. It will simply not be possible to ship vast tonnages of goods around the globe to satisfy consumer demand.

Of all of the transport systems railways seem best positioned to weather the storm. They will become pivotal to the success of the economy in the future. This is because the railways (in principle) can operate without dependence on oil and have done so in the past.

3. Transport Energy Options

The cost and availability of oil based fuels will virtually preclude its use for widespread personal and commercial transport. Its use will be confined to specialist transport applications (military, emergency services, etc.) for which its use is essential. So what energy alternatives are available?

1. Biofuels which are sufficiently highly refined as to replace petroleum products may be limited in application. The ERoEI (Energy Returned on Energy Invested) of some biofuels is marginal, although those derived from algae appear to have good potential. Fuels based on crops are also

grown on land suitable for food production, of which the latter will obviously take priority. The problem is that there simply may not be sufficient land to grow crops to replace the enormous quantities of oil currently consumed. Biomass cannot currently be used for transport use except in *external combustion engines* of which steam engines and Stirling engines are the best known.

2. Hydrogen. As of yet a process has not been developed which requires less energy to produce and store hydrogen than can be got back from the fuel (i.e. a negative ERoEI). Until this issue is overcome hydrogen is simply not a viable fuel as there are better (and safer) ways of capturing and storing energy.

3. Renewable energy. This variously covers wind, wave, tidal, solar and geothermal energy. The processes either captures solar energy (directly or indirectly) or draws upon energy stored within the Earth (as kinetic energy or heat). They are most usefully captured as electricity or heat. The key issue here is that it is difficult to apply this energy to transport use. The two possible exceptions are water borne sailing craft and the solar powered cars that race across Australia.

For renewable energy to be viable for transport a means of *storing and recovering* energy is required. Some options are discussed in the following points.

1. Battery powered vehicles have been around for a long time, however range is limited and to increase it (by adding more batteries) reduces payload. Battery technology will no doubt improve, but a step change in performance will be required before they can seriously be considered for anything other than local transport.

   As transport accounts for a significant proportion of world energy use then a corresponding increase in base load electricity generation will be needed to meet this additional demand. Resources of the metals required to make batteries may be as limited as fossil fuels.

2. Capacitors have developed considerably in the last few years. Super capacitors are now used on some hybrid vehicles in place of batteries. Total practical energy storage is still considerably less than batteries.

3. Heat storage has yet to find widespread use, however with modern thermal insulators there could be potential applications. It is relatively easy to convert electrical energy to heat. The two most likely options for converting heat back to mechanical work are the steam engine and the Stirling engine.

4. Pressure potential energy storage. Once again this is an old technology; fireless steam locomotives have been in use for many years in industrial use. Very hot pressurized water is pumped into a storage vessel and is used to drive an otherwise conventional steam engine. Obviously a ready source of hot water is required and once again range is limited. Pressure can also be stored hydraulically (large and heavy) or as a gas (entails wastage of significant energy as heat as the gas is compressed), neither of which is particularly suitable for transport.

5. Kinetic energy storage. Most commonly the flywheel is used. Kinetic energy storage is not very dense and is best suited to short term storage/recovery. There is a rail based vehicle (Parry People Mover) which uses flywheel energy storage for traction. The flywheel is charged at the stations.

One key factor of all stored energy systems is that they are not self regenerating. In the context of rail operations if you run out of energy on the open track you are stuck! Therefore stored energy transport can only be operated realistically at a range much lower than the theoretical maximum.

Given the state of the above technologies it seems likely that steam traction could well have a role to play in the operation of tomorrows railways for the following reasons.

1. The technology exists and is proven.

2. Steam can burn relatively unrefined biomass, waste products or coal.

3. It is improbable that any of the alternative technologies could reach a stage of maturity sufficient to justify widespread use in the timescale available.

4. From Where Will Come the Energy?

It appears that there may be an opportunity for steam to return to the railways principally because there may not be an alternative. However, the future of steam is far from assured. The coal shortages will be hot on the heels of the oil shortages. As other transport modes tend towards electric based technologies (e.g. battery power) the base load power demand will increase dramatically. Unless the production of renewable energy sources increases substantially much of the demand will have to be met by coal powered plant. Nuclear power is facing a similar (though slightly longer term) shortage of fuel and the timescales for constructing these plants are comparatively lengthy.

Possibly there will be 20 years (or so) breathing space to “Peak Coal” which could be used to develop alternative fuels. For biomass to be a viable fuel it will need to be burnt with minimal refining to maximize the ERoEI. Wood looks like a possible alternative as it can be grown on land unsuitable for crops. The by-products of other processes (e.g. straw from wheat production or bagasse) could also be considered. Another possibility requiring further research is the combustion of glycerin which is a waste product of bio-diesel manufacture.

In short, it is far from clear how steam of the future will be fuelled. In principle, the steam locomotive has the potential to burn a wide variety of fuels and coal appears to most viable in the short term.

5. Electrification

Without doubt most European railways, metros and light rail systems, existing and new, will be electrified in the future. However, large sections of many rail networks are not electrified and traffic levels dictate that they never will be. This is especially true in the USA and other countries where the distances are great. Electrification is time consuming and costly to install. To keep networks operating alternative traction will have to be considered over the non-electrified route mileage.

6. Private Transport

With the demise of the motor car it is likely that (rather than adopting a wholly public transport approach) the population will be forced to use stored energy vehicles. These will derive their energy from renewable electricity sources and store it in batteries, capacitors, thermal masses, or whatever technology becomes available. Such vehicles would be fine for local transport, but as with all devices where energy is stored, mass and size have an important influence on range. For longer range journeys there are two options:

1. Use the train for the whole journey with walk/bike/bus for the "last mile".
2. Drive the stored energy vehicle onto the train. This solution actually exists in the form of the Channel Tunnel Shuttle. The stored energy vehicles could recharge whilst in transit and passengers would retain their, all important, privacy.

Fig.1. Le Shuttle, Channel Tunnel drive on – drive off service

7. Commercial Transport

Given that commercial and private transport will be governed by similar constraints it is likely that goods will be moved in a similar manner. Goods will be taken to the rail head by stored energy road vehicles. The train will be used for most of the journey and stored energy vehicles used for the "last mile".

Wagonload freight will probably be carried in intermodal containers as used today. Part wagon load freight could well be transported in wheeled trolleys of pallets. The other alternative is that commercial vehicles are also able to use roll on – roll off services, at the expense of transporting unnecessary mass about the country. Trainload freight, long the preserve of the railways, will probably remain substantially unchanged.

8. Trunk Routes

Rail trunk routes will be electrified. It is possible a high speed network of trunk routes will evolve for the use of passenger and shuttle services. These will be segregated from the existing network as the speeds will be incompatible with most secondary services. Also the additional loading gauge required for intermodal traffic probably makes most existing routes unsuitable.

With the existing main lines freed from the requirements of high speed travel, they would be left to handle the normal freight and secondary passenger services.

Railway operations may well become centred around strategic hubs connected by high speed electrified links. At each hub would be marshalling yards for freight as well as links for passenger traffic to the main urban centers.

9. Secondary Routes and Branch Lines

Many of these will remain non-electrified simply because the level of traffic will remain modest. Whether closed routes will be reopened depends on the range of the stored energy vehicles feeding the railhead. The secondary routes may become the domain of a new generation of steam locomotives. It is possible that there will be greater use of bi-modal stock (such as the Class 325s in the UK) where they can be loco hauled for parts of the journey and use electricity for the remainder.

10. Potential Steam Locomotive and Traffic Types

It is envisaged that the above traffic requirements could be satisfied by three basic locomotive types. All would embody the most advanced state of the art steam technology[1]:

1. 2ATT. Of the same basic proportions as the BR Standard 2MT tank. This would be capable of handling short range traffic (<50km) up to approximately 200 tons. Traffic would include local passenger services and freight between population centers and the hubs.

Fig.2. BR Standard 2MT Tank – Basis of the 2ATT

2. 5AT: This loco would be capable of handling inter-regional traffic (50km – 200 km) on secondary routes where electrification is not viable. Train weights, both passenger and freight, would be up to approximately 500 tons. The general performance and technical specification of a locomotive of this type have been defined by the 5AT Group – see footnote.

[1] Details of the proposed 5AT (**A**dvanced **T**raction) can be found on www.5at.co.uk. The basic principles embodied in the 5AT can be applied to a variety of locomotive designs. The AT technology has all been tried and tested is some form. There are no radical new technologies - simply sound application of the best known engineering practices. The resulting machine is twice as efficient as traditional steam.

Fig.3. BR Standard 5MT – Basis of the 5AT

3. Freight AT. This loco would be suitable for trainload freight. The size of the locomotive would be matched to the intended traffic and local operating conditions. Trains might be between 500 and 5000 tons.

Fig*.4. An EAR Bayer Garratt – Basis of a Freight AT?*

If possible locos should be designed with alternative fuel types in mind. Unlike the 5AT in it present form the emphasis will be on economy rather than performance.

11. International Travel

On the whole it is reasonable to expect journey times to suffer. With the demise of conventional air travel, most trans-European passenger travel will be by extension of the high speed rail links. Outside Europe it is hard to see how intercontinental travel will develop without enormous investment in infrastructure.

Trans Atlantic travel will be a whole different problem. Air travel, even by airship, is likely to be limited simply because helium is also a finite resource (currently it is only found naturally in certain rock structures). Here we might see the return of sailing ships; the fastest trans-Atlantic sailing record stands at about 5 days. Scaled up sea- borne freight is also likely to make greater use of sail power. It is possible that an alternative auxiliary power source (solar power, or maybe steam) will be needed to maintain something like regular voyage duration.

Fig.5. The Multihull Groupama 3. At time of writing it had just set out on an attempt on the 4 days 4 hours transatlantic sailing record – technology to be scaled up?

12. The Rest of the World

The scenario outlined above is based around UK conditions. Most of the scenario will probably apply to European railways, where the use of electrification will become increasingly widespread. Transcontinental railways face a whole different set of circumstances. In the US in particular there is a heavy dependence on diesel for long haul rail services. Once again steam would appear to offer the only viable alternative when one considers the US's (allegedly) vast coal reserves.

13. Conclusion

Taking an objective view, steam traction could have a role to play on tomorrow's railways. The technology already exists to bring steam back in a modern form with very little development. The inherent flexibility of the steam locomotive allows it to operate on a variety of fuels, many of which could be waste products or carbon neutral. Objections on grounds of poor efficiency are valid; however two points should be borne in mind:

1. Electric traction, where the electricity comes from coal fired plant, has *overall* efficiencies not dissimilar to modern steam (about 13% to 16%).

2. Development of the steam locomotive is far from its peak. A mere fraction of the investment that has been made in developing internal combustion engines would produce substantial improvements to the steam locomotive.

The biggest obstacle is not technology – it is the clouded perception of an oil dependent world.

Jamie Keyte
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About the Author:

Jamie Keyte *(BEng Hons), A.M.I.Mech.E. - After graduating in 1995, he worked as a structures and power systems engineer for Bombardier Transportation in the UK. For some years he worked for a hydraulic systems company and since 2006 he has been involved in the formation of Hyrdovane Transit, the transport air compressor division of Compare. He has been involved with the Mid-Hants Railway since 1988 and the 5AT Project since 2004.*