Furrer+Frey®
Overhead contact lines

March 2017

White Paper

Developing Sustainable Multimodal Transport Solutions for Wales

Contents

Figure 1 Llandudno in Wales taken from http://www.seftoncourt-hotel.co.uk

Introduction and Synopsis

This white paper explores how existing transport modes can be developed to become more interconnected, sustainable and environmentally friendly. Furthermore, this document seeks to demonstrate how the electrification of all forms of public transport can support Welsh aspirations in a cost-effective manner.

The Welsh Government has a growing reputation in promoting and supporting sustainable public transport. In 2008, ‘The Wales Spatial Plan’ focused on valuing and enhancing the environment for national, regional and local communities. Transport was identified as a key contributing factor towards this in ‘The Wales Transport Strategy’ paper produced in the same year. In 2015, ‘The Well-Being of Future Generations Act’ was passed, committing towards a healthier, more cohesive and globally responsible nation.

These sustainability goals were praised by the United Nations Director for Sustainable Development, with ‘One Wales, One Planet’ highlighted as a leading strategy for the rest of the world to follow[i].

[1] Pictures: front cover, page 3 and 4 – provided by Wales Millennium Centre. Title copyright Phil Boorman, page 2 and 3 – Flourish NB

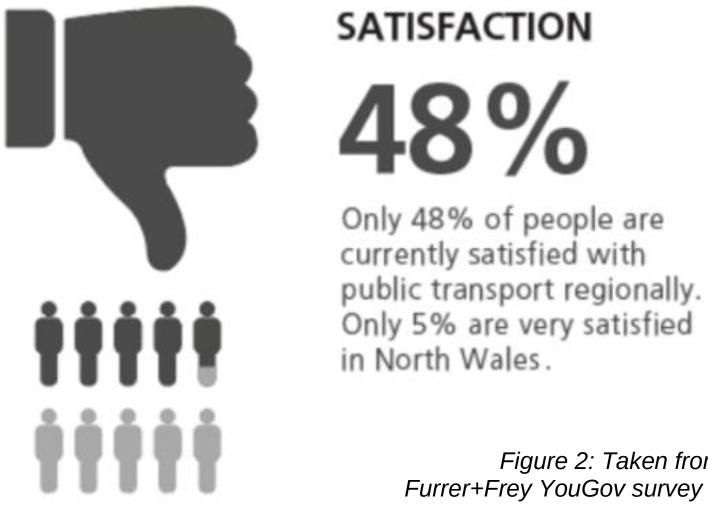


Figure 2: Taken from Furrer+Frey YouGov survey – January 2017

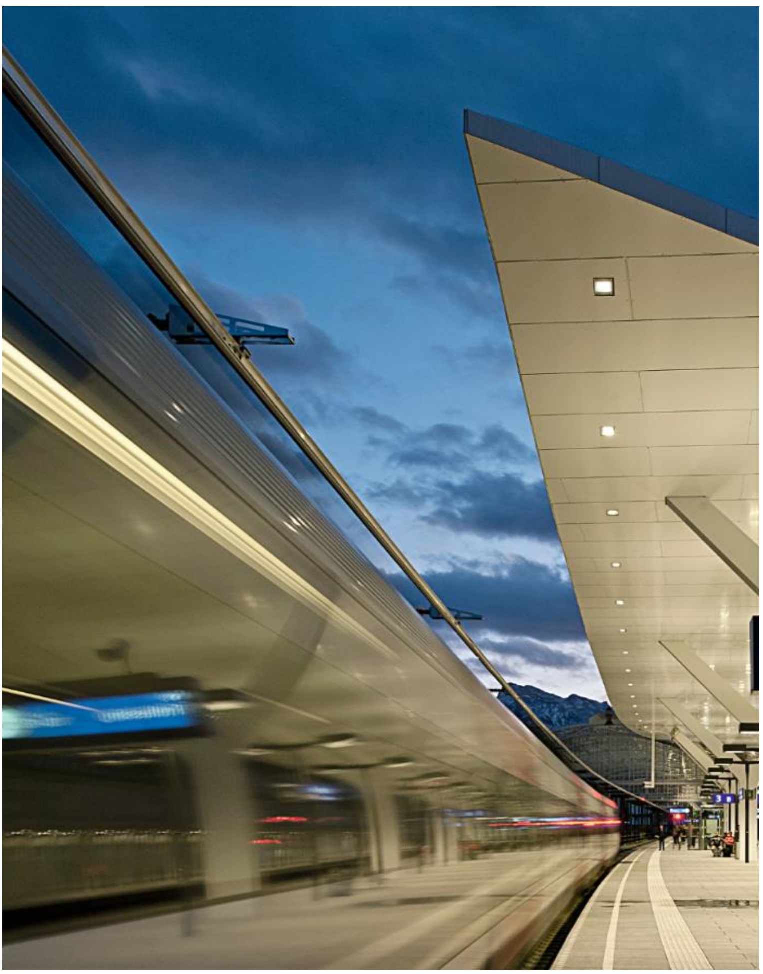


Figure 3 Photo from Salzberg Station. Electrification designed by Furrer+Frey

The Brundtland Commission defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”[ii].

In terms of transport this means using renewable energy sources to power new connecting routes, regenerating braking energy and promoting public transport. Consideration should be given to the impact that any new transport link will have on ecosystems and biodiversity; this includes the visual and auditory impact on the surrounding environment. This is particularly true as Wales moves towards a greater percentage of electricity being generated from renewable sources. Moving towards green energy sources reduces harmful emissions which positively impacts climate change and improves health.

Transport in Wales has the potential for significant sustainable growth. A well-integrated transport system facilitates easier access to jobs, education, areas of tourism and culture as well as supporting wider economic growth. The promotion of public transport reduces the reliance on private car use, leading to a lower consumption of a finite resource.

This white paper will demonstrate how green technology developments, such as low cost electrification and rapid charge, can successfully integrate the rural and urban communities of Wales.

Any new public transport initiative should be:

+ Scalable: eliminating the risk of 'all or nothing' solutions when not required. This enables projects that would not be economical under traditional electrification systems
+ Cost-efficient: deployment can be matched to available budget
+ Applicable to rural, intercity, urban and interurban transport
+ Aiming to lower operating costs
+ A potential for increasing employment in Wales
+ Removing carbon emissions: reducing, and potentially eliminating pollution hazards to Welsh citizens; in 2012 the World Health Organisation pronounced diesel exhaust a Class 1 carcinogen.[iii]

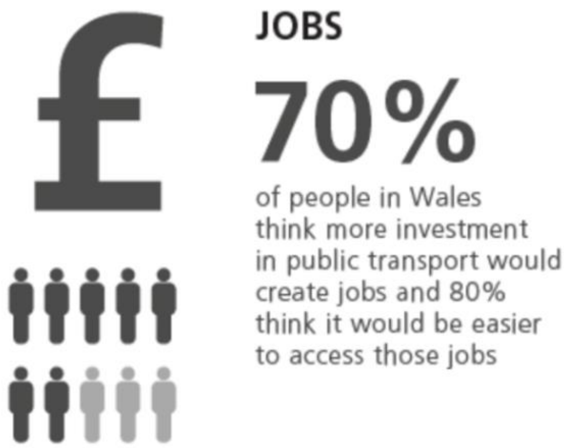


Figure 4: Taken from Furrer+Frey YouGov Survey – January 2017

A coherent transport plan and multimodal electrification can offer all of these benefits, and will assist the Welsh Government in meeting its transport aspirations.

Figure 5 Link between the One Wales Transport Strategy, The Wales spatial Plan and The Well-being of Future Generations Act 2015

Historical Context

Wales has a strong history of innovation in public transport. The Swansea and Mumbles Railway was the world's first passenger railway service. Built in 1804 to move limestone from the quarries of Mumbles to Swansea and to the markets beyond, it carried the world's first fare-paying railway passengers on 25 March 1807. It moved from being horse drawn to steam locomotion, and finally converted to electric trams, before closing in January 1960, in favour of motorbuses. Up to this point, it was the world's longest serving railway.

Trams and trolleybuses have also contributed to Wales' public transport system. Until 1970 Cardiff had a substantial trolleybus system of 14 routes, based on its older tramway routes.

Until the Beeching railway cuts of 1963, railway branch lines threaded the country, providing a public-sector transport infrastructure that dwarfs the current network. Passengers could ride trains to a much greater number of Welsh destinations, and where necessary be transferred to GWR controlled busses (today, the remaining routes now fall under Arriva North West and Wales).

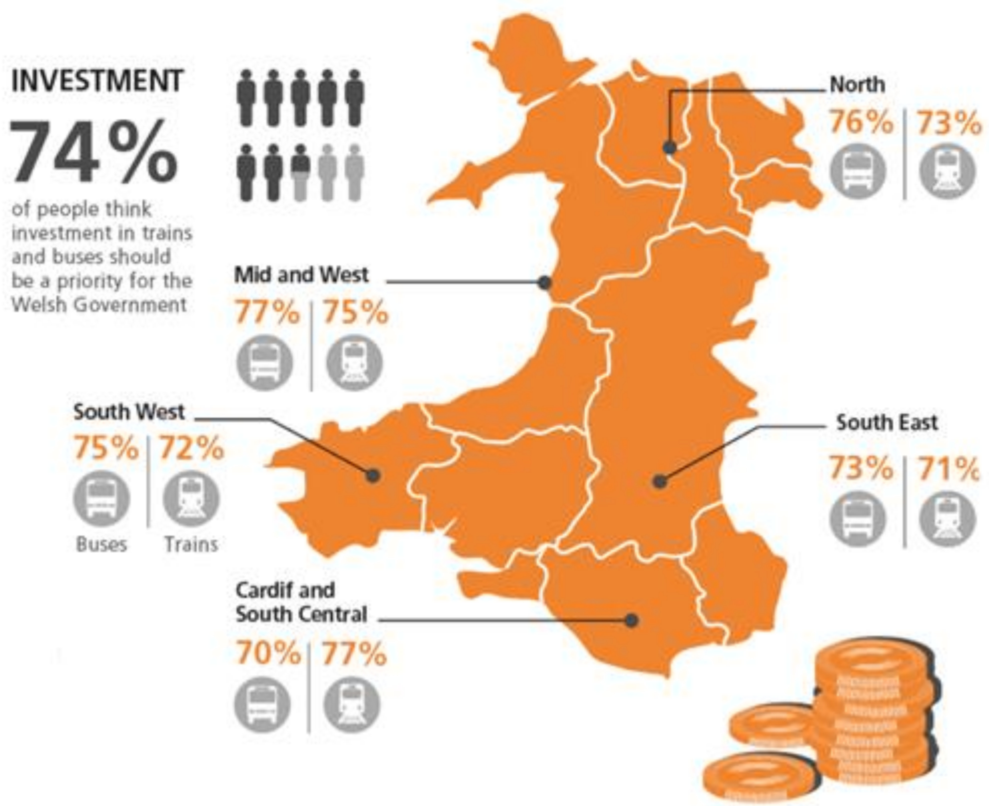


Figure 6 Taken from Furrer+Frey YouGov Survey – January 2017

Freight

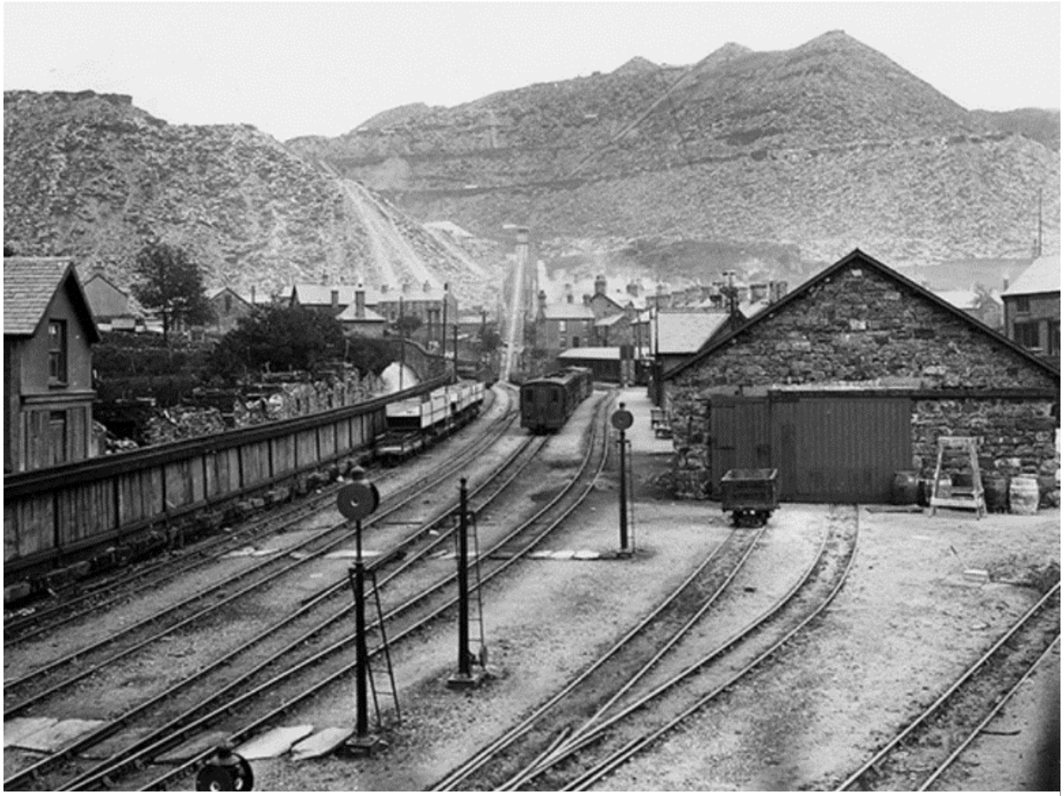


Figure 7 Proto original Ffestiniog Railway Station at Blaenau Ffestiniog – circa 1870

Prior to the Beeching cuts, rail freight was a common carrier and would have been managed using a multimodal solution. This included transfer from main to branch line, and onto road haulage, at the closest point of access to the delivery site. At peak utilisation in 1924, the system carried nearly 75 million tonnes of freight (approximately the same as carried across the whole of the UK today).

Coal, slate, and china clay required heavy rail links to Wales's ports. The lack of mechanised road transport led to an interconnecting set of rural branch lines running north to south, linking with the mainline running east to west. Additionally, narrow gauge industrial railways provided vital infrastructure in parts of Wales where standard gauge was uneconomic, or even physically impossible.

After World War II, competition to rail based freight increased with an influx of reliable Lorries and other delivery road vehicles, the latter hobbled by the price structures required of a common carrier. 1963 was also the year the British Transport Commission was abolished, along with its near monopoly on long distance freight. The side-effect of this though was to abolish the integrated management of public transport and of intermodal freight.

Historical Decline

The Beeching Report, published on 27 March 1963, was a result of a narrow cost analysis approach, which did not consider the social and broader economic implications of biasing transport policy toward road and individual car ownership. Cheap oil, a negative perception of public transport by the UK Government, and a drive to return British Railways to profitability led to many rural branch lines being eliminated.

The Beeching Report had a particular impact on Wales. It focused on connecting large urban centres, not a wider network and rural networks. Wales had a public transport system biased towards rail supporting a proportionally high rural population. Even today the 2011 census results show that Wales has a rural population of 1/3 compared to 1/5 in England, thus was disproportionally impacted by the Beeching Report.

Until the 1980s much of the British bus network was in public ownership, either by the state owned National Bus Company or by municipal owned bus operators. This changed with the implementation of the Transport Act 1985 on 26 October 1986, which included the deregulation of bus services in Wales. However, Wales retained significant public ownership of municipal buses in Cardiff and Newport; two of only 12 are still in public ownership.

Figure 8: Photo Furrer+Frey light rail system

Current Public Transport in Wales

Rail network

Wales has a rail network focused along its east to west axis, but with relatively poor north to south connectivity. In total, the Route covers 923 route miles and 1,487 track miles (see figure 9)[iv].

Figure 9 Current Rail Networks in Wales. Original source information DfT

The rail network serves a diverse range of markets including long distance interurban flows, significant daily commutes to Cardiff and Swansea, and the less frequented commuter routes of Wrexham, Newport, Shrewsbury and Hereford. It also includes the western end of the Great Western and London North Western 'intercity' main lines. There is also a rural market and considerable freight flows both within Wales and cross-border.

Rail passenger journeys in Wales have been increasing over the last decade. There were nearly 29 million rail passenger journeys which either started or ended in Wales in 2013-14, an increase of over 1 per cent compared to the previous year. Over two-thirds (68 per cent) of these journeys were within Wales. During 2013-14, stations within Cardiff local authority were the destination of almost two-fifths of rail passenger journeys within Wales[v].

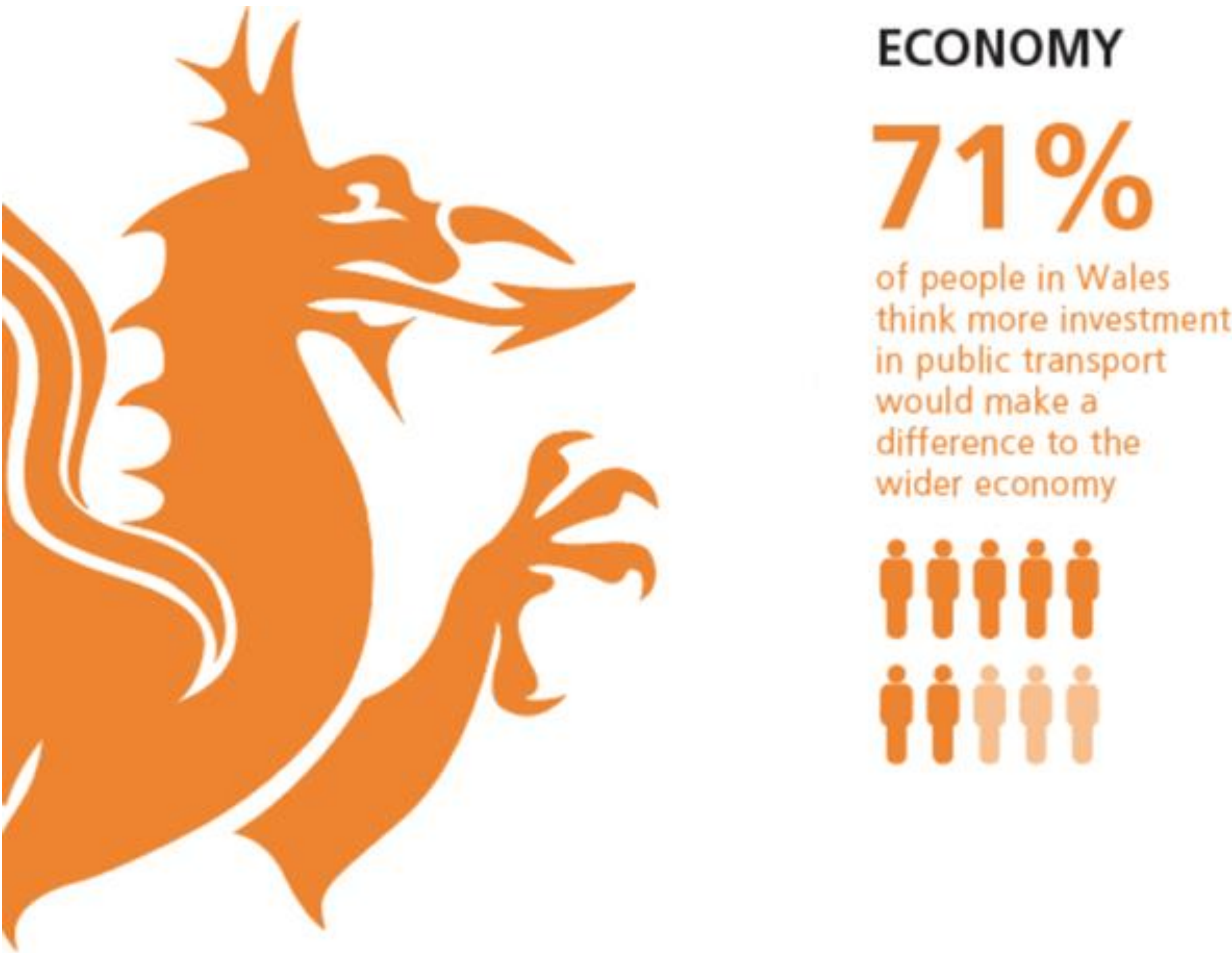


Figure 10 Taken from Furrer+Frey YouGov Survey, January 2017

Network Rail has split the Wales Route into five distinct markets: long distance, interurban, commuter, rural and freight

Long Distance markets

Long distance services run between south Wales and London currently use Class 43 eight-coach formation high speed trains (Intercity 125). These services cater for the long-distance market between Wales and London. Within Wales these call at Swansea, Neath, Port Talbot, Bridgend, Cardiff Central and Newport.

Figure 11: Furrer+Frey visualisation – using Furrer+Frey High speed system

The frequency of services is every half hour between Cardiff and London, with half-hourly services from Swansea to London in the peak, and hourly services in the off-peak. These trains also support regional commuting. As this stock's design was for intercity, long distance and low stop frequency, they are not optimised for the way the South West and Wales have evolved in terms of a passenger market.

The new Class 802 Hitachi bimodal rolling stock, being introduced as part of the Great Western Mainline Electrification programme, should reduce the excessive overcrowding that occurs during peak times. It also has a higher acceleration, compared to the Class 43 stock they replace. Journey times from Swansea and Cardiff to London will be 15 minutes quicker (reduced from 3 hours to 2 ¾ hours and from 2 hours to 1 ¾ hours respectively).

In the North of Wales the current franchiser has increased the frequency between Chester and Manchester, which feeds into the Northern Hub, Manchester Airport and North Wales. There are regular long distance services between Holyhead and London Euston, using Super Voyager trains running at up to 125mph on the West Coast Main Line in England. This calls at principal stations including Bangor, Llandudno Junction, Colwyn Bay, Rhyl, Prestatyn, Flint and Chester. There are six daily through-services from north Wales to London, and seven through-services from London to north Wales.

The 2007 Wales Rail Planning Assessment (WRPA) forecasts that the long-distance sector will see growth of up to 40 percent in passenger numbers between 2005 and 2026.

Figure 12 Burnham – Photo December 2016

Commuter market

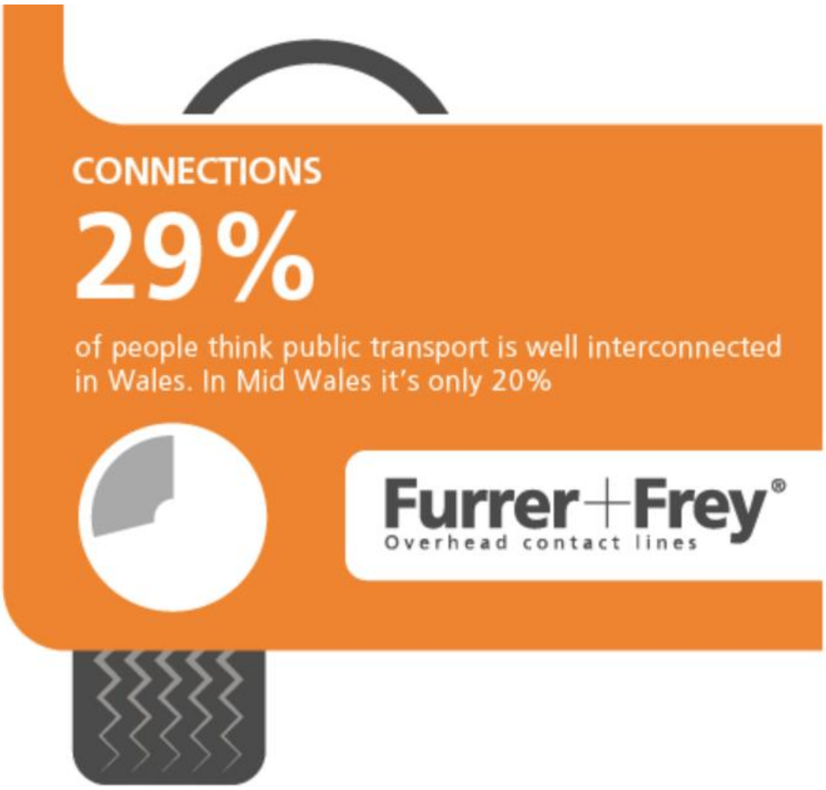


Figure 13 Taken from Furrer+Frey YouGov Survey - January 2017

The long-distance services between Swansea and London also serve the regional commuter market between Swansea, Cardiff, Newport and Bristol and there are heavy peak flows in both directions. There are also strong commuter flows between Severn Tunnel Junction and Bristol Temple Meads.

The busiest commuter market in Wales is on the Cardiff Valleys network, where demand continues to grow at a rate of around 5% per annum. South East Wales is the most densely populated area and the current franchise documentation issued by Transport for Wales, acknowledges this with a high focus on the Core Valley and Cardiff Metro Phase 2.

The WRPA forecasts that the commuter sector will see a growth of up to 50% in passenger numbers between 2005 and 2026.

However, rolling stock is ageing and has become less reliable; this already provides an unattractive offering to potential commuters. This unattractive offering is magnified by confusing ticketing and difficult transfers between modes of public transport. Tempting people to use public transport instead of their cars means providing a reliable, transparent and pleasant travel environment.

Conventional overhead line electrification would require new stock to be introduced.

Interurban services

There is a strong interurban market in Wales, with regular through-services between west Wales/Cardiff and Manchester, north Wales and Manchester, between Cardiff and Holyhead (2 hourly), Cardiff and Bristol, and Cardiff, Gloucester and Birmingham.

The Welsh Government funds a limited-stop express train from Holyhead and Cardiff for the business market, with one return journey per day, as part of its policy to reduce journey times between north and south Wales.

The WRPA forecasts growth in demand of up to 35%-40% in passenger numbers in the interurban sector between 2005 and 2026.

Figure 14: Furrer+Frey visualisation for BLS railways

Key freight markets and traffic flows

The South Wales Mainline, North Wales Main Line and the Marches Line between Newport and Shrewsbury form the basis of the national freight network in Wales. This network supports the movement of freight from branch lines and has several freight-only lines.

Steel, coal and petrochemicals are the predominant traffic in south Wales and there is also a moderate flow of container traffic between Cardiff and the Midlands and Southampton. In west Wales, the oil refineries near Milford Haven generate long-distance flows to Westerleigh and to Theale. The Central Wales Line is very occasionally used for freight diversionary purposes. Traffic is dependent on the output of the Port Talbot Steel Works and the coal trade. As coal for electricity generation is significantly reduced this has reduced overall freight demand.

The Vale of Glamorgan Line offers a freight diversionary route to the South West Mainline between Cardiff and Bridgend. The principal traffic over the Swansea District Line is steel traffic to and from the TATA works at Trostre in Llanelli. Tesco also use freight trains from Daventry to Wentloog in Cardiff, for fast moving of consumer goods into the retailer's regional distribution centre at Magor.

The Marches Line, between Newport and Shrewsbury, has experienced freight traffic growth and offers an alternative option to routing traffic to the north via the busier, steeply graded Lickey route through Bromsgrove and Birmingham. The majority of the traffic is steel, scrap metal, coal and intermodal containers.

Figure 15 Taken from https://goo.gl/agju89

Rural market

Large parts of Mid Wales, West Wales and North West Wales are rural or low urban density in nature. Whilst these areas are often well served by interurban train services running on the mainline, the pattern of traffic on the feeder branch lines is less frequent.

There is growing demand on the Cambrian Line for leisure and business journeys to Aberystwyth, Shrewsbury, Birmingham and Birmingham International Airport.

The Central Wales Line and the Blaenau Ffestiniog Line are typical examples with several journeys in each direction per day and frequent stopping patterns at unstaffed stations. The Central Wales Line is popular with visitors and tourists and there are various promotions on the line to encourage demand, including free concessionary travel for older people in the winter months.

Across Wales, there are good connections between rural services and interurban services; some rural services continue through to serve the interurban market. A good example of this is the Cambrian service, which is rural in nature, between mid-Wales and Shrewsbury and which then continues to serve the interurban market between Shrewsbury, Wolverhampton and Birmingham.

The WRPA forecasts growth of up to 35%-40% in passenger numbers in the rural sector between 2005 and 2026. Again, these services are dependent on ageing stock, some of which will shortly become life expired.

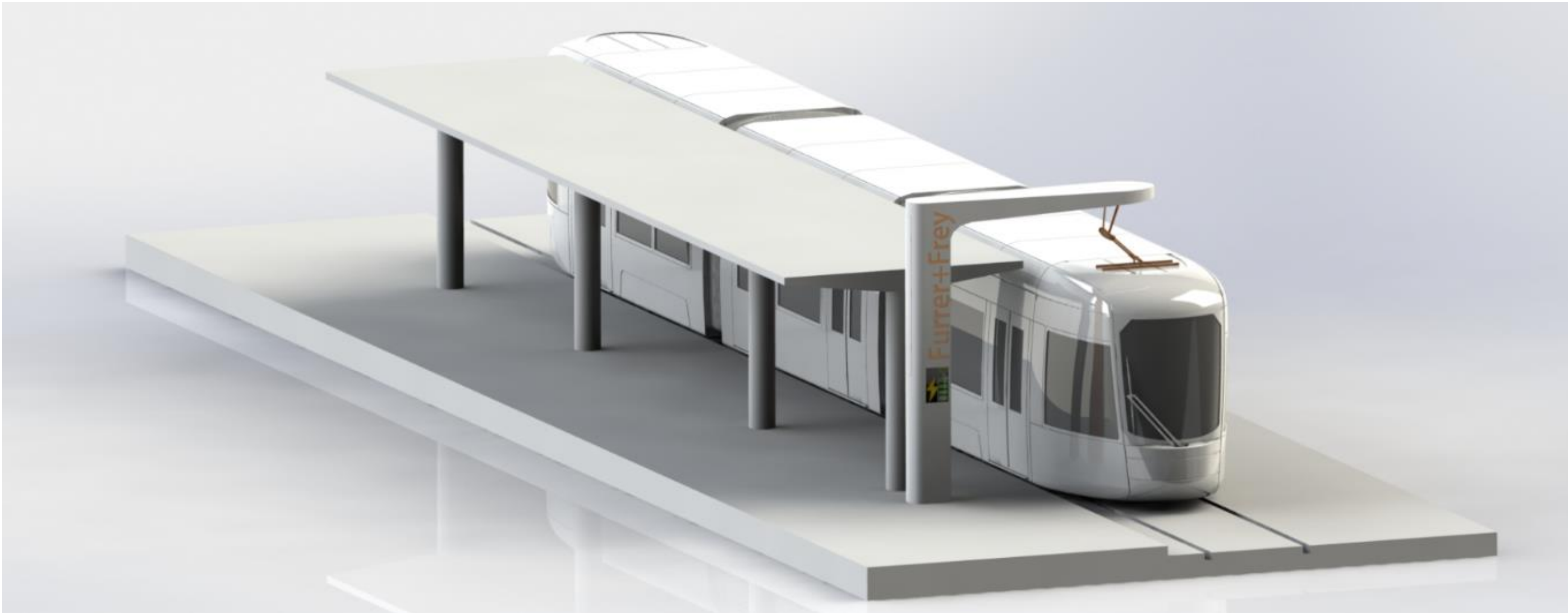
Figure 16 Llanelli - Photograph - James Davies/Alamy

Road public transport

The council owned Cardiff Bus and Newport Transport, in their respective cities, predominantly provides bus services. Private sector operators in Wales include:

+ Stagecoach: provides services on routes centred on Cardiff and the South Wales Valleys, with a low-cost coach service from Cardiff to London as part of its Megabus brand
+ First Cymru: provides services centred on Bridgend, Neath Port Talbot, Swansea, Llanelli, Carmarthen, Haverfordwest and South Pembrokeshire, also providing a key link from Bridgend/Swansea to Cardiff
+ Arriva North West and Wales: provides services through North Wales
+ NAT Group: provides services between East and West Cardiff, and from Central Cardiff to Cardiff Airport, Pontypridd, Barry and Bridgend
+ National Express: offers services to major towns in England: Bristol, London, Liverpool, Manchester, Birmingham, Nottingham, Sheffield, Hull, Bradford, Newcastle upon Tyne, Leeds and Bradford
+ Megabus: operates services from Cardiff to Bristol, London, Birmingham, Manchester, Leeds and Newcastle upon Tyne
+ TrawsCymru: medium to long distance coach services, designed to complement the existing rail network

Figure 17 Computer generated visualisation of tram stop using Furrer+Frey All-In-One rapid charge station



Bwcabus

The Bwcabus network is of substantial importance to the rural community. The concept was built around a taxi/bus hybrid system, giving a significant boost to the rural population of Wales. Evidence of this includes[vi]:

- More than 58,000 customers use the Bwcabus integrated network (including Bwcabus, T1, T5 and 460 services) per month
- Bwcabus is helping to sustain the rural economy. A 2013 survey has shown that passengers are spending on average between £10 – £20 each time they are visiting their local towns
- Bwcabus has increased bus travel in rural Carmarthenshire and Ceredigion. In total over 170,000 Bwcabus journeys have been completed
- The service continues to grow, with Bwcabus passenger growth of 8% in 2015

Since 2009 the strategically important 460 route connecting Carmarthen and Cardigan has shown significant and sustained growth. The number of passenger journeys per day on the 460 service has increased by over 50%

- Bwcabus is fully integrated with the Traws Cymru and other Strategic Public Transport Services
- The service integration is combined with through ticketing to offer seamless travel between Bwcabus services and strategic routes including Traws Cymru routes

Figure 18: Furrer+Frey Rapid Charge Station - Gothenburg

+ Accessibility modelling shows the levels of accessibility to employment have improved significantly. Average journey times to the nearest employment centre have reduced from 52 minutes down to 27 minutes since the introduction of the Bwcabus service

+ Bwcabus has achieved behavioural change by making public transport more attractive to car users. 48% of respondents surveyed in 2013 reported they have reduced the number of trips made by car

+ Bwcabus is internationally recognised. Interest in the Bwcabus pilot has been considerable and has extended across Europe

+ Bwcabus is an award-winning service, it has won three prestigious awards in recognition of its success

+ Bwcabus runs 11 fixed timetable services per week. These fixed Bwcabus services offer 50+ return journeys per week in addition to the ability to book demand responsive journeys 6 days per week 7am – 7pm

+ A 2013 survey of 93 users of the Bwcabus service revealed extraordinarily high customer satisfaction. The results showed that 98 % of passengers are overwhelmingly satisfied with the service overall

+ Bwcabus has developed a strong brand identity. It is intended that the brand will be consistent with Welsh Government transport branding, including the Traws Cymru service

Figure 19: Furrer+Frey Rapid Charge Station – Gothenburg

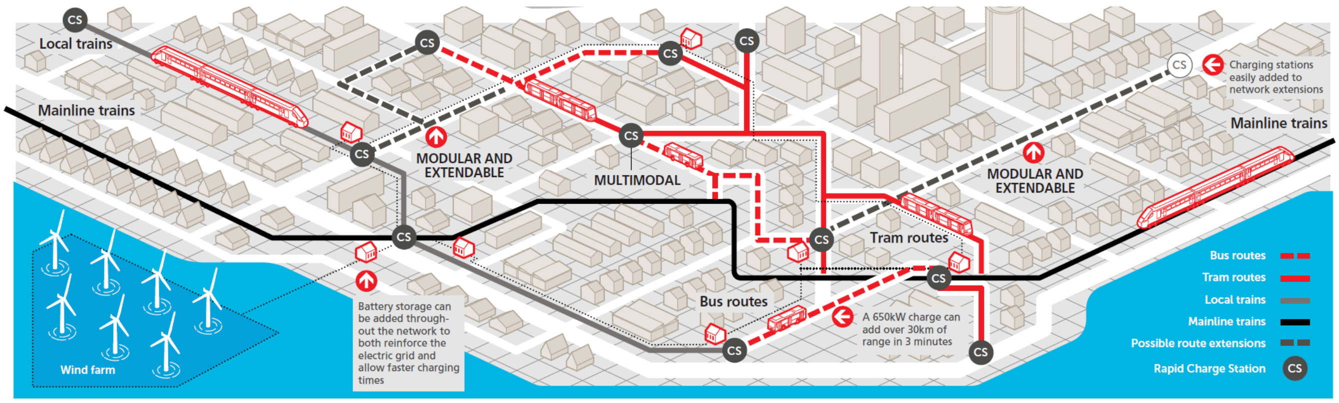


Figure 20 Furrer+Frey impression of a multi-modal rapid charge powered system

Personal Car Use

The use of personal cars has obvious user costs and environmental impacts. The devolved government already recognises this; in the Wales Transport Strategy, an 'over-dependence on the private car' is highlighted. In 2012 these statistics were issued:

+ The use of the car, either as driver or passenger, dominates personal travel
+ The car accounts for 69 percent of total trips made in 2011 and 2012, and 83 per cent of the distance covered in a year
+ The top two reasons are travel trips for shopping and for commuting and business each with around a fifth of trips
+ The next are 'visiting friends (and relatives)' and travel for all sorts of leisure purposes, including 'just walking', both with around 15 per cent of trips
+ The last three broad reasons for travel are 'education and escort education', 'other escort' and 'personal business' each with a tenth of trips
+ An average one way personal travel trip in Wales covered 8 miles. A typical walking trip was for less than a mile; it was 9 miles when made by car or other private transport and was for 6 miles when made by local bus
+ Personal travel in Wales peaked in 2004 and 2005, fell back to a trough around 2007 and 2008 and since has recovered steadily
+ 8 out of 10 journeys to work are by car, and this proportion has remained broadly unchanged for 10 years
+ Wales has the highest proportion of people travelling to work by car of any region within Great Britain[vii]

Economically and environmentally sustainable solutions that are easily accessible as well as scalable, particularly in terms of matching deployment to available budget, are an obvious resource for freeing Wales' population from car dependency. They also support the Welsh Assembly's current public transport initiatives, particularly in rural areas.

Multimodal electrification, both rail and road, can provide such a scalable solution, and potentially provide employment in Wales, beyond that required for installation.

It can make use of the Principality's rich resources of environmentally sustainable power, removing diesel power, and its associated carbon dioxide and carcinogenic emissions, from public transport.

Figure 21: Furrer+Frey photo from testing of Network Rail's high output plant system in Germany

One Wales and the Future of Transport

The Wales Transport Strategy shows the need for a balanced, socially orientated transport strategy. The Welsh government has recognised that transport is an area with a lot of potential for sustainable development.

Sustainable Transport

Of the 17 sustainable development goals adopted by the United Nations in 2015, the following can be enhanced by intelligent transport developments:

+ **Health,** by reducing/removing the sources of noxious emissions and encouraging an active lifestyle by using public transport
+ **Education,** by improving/allowing equal access to educational facilities across the country
+ **Economy,** by improving access to leisure and tourist attractions, stimulating the economy in areas not currently linked to wealthier conurbations
+ **Infrastructure,** by building and extending transport links to connect the country and attract sustainable innovation and development
+ **Habitation,** by having a resilient and reliable transport network that encourages long term urban planning. Long term urban planning requires political commitment
+ **Consumption,** by reducing reliance on fossil fuels and encouraging the use of electrically powered transport from renewable energy sources
+ **Climate,** by reducing emissions of greenhouse gases which are recognised as a leading cause of climate change
+ **Institutions,** the transport operating companies will set a standard for the rest of the country in how to use green technologies effectively
+ **Sustainability,** by developing transport to meet the needs of the future and present generations

Figure 22 Tenby (Photo: Skycamwales.com / Pembrokeshire Photography)

Pursuing sustainability in terms of transport necessarily involves the reduction of emissions. This can be achieved by using hybrid or electric vehicles for private transport, but this is an area of research still in its infancy. The industry continues to undergo significant developments, but will still increase congestion on the roads, a problem that can only be conquered with development of public transport.

In the realm of public transport, the use of overhead line electrification for trains and innovative rapid charge buses are leading the way in terms of sustainable innovation. Both are electrically powered meaning that there are no emissions directly produced unlike diesel powered trains and buses. If the rail system is upgraded to support the movement of freight, Wales will see the benefit of a better-connected sustainable network. Once other modes of transport are integrated, public transport could overtake private-car use as the primary choice for commuters. This would relieve the strain on the roads and help develop the transport system of Wales.

Electrification, as described in the rest of this paper, can also showcase Wales as an exemplar of modern, social responsible and economically relevant transport. However, this only forms one part of a wider and better integrated public transport market that is easier to access. To highlight the current issues with access these can be summed up succinctly in Lonely Planet's description of train travel in Wales:

"You can roll up to a station and buy a standard single (one-way) or return ticket, but this is often the most expensive way to go. Each train company sets its own fares and has its own discounts, and passengers can only use tickets on services operated by the company that issued the ticket.

You might find that the same journey will have a different fare depending on whether you buy it at the station, over the phone or online. The fare system is so bizarre that in some cases two singles are cheaper than a return ticket, and even a one-way journey can be cheaper if you split it into two (ie if you're going from A to C, it can be cheaper to buy a single from A to B, and another single from B to C; go figure)".viii

Figure 23 Visualisation of Furrer+Frey rapid charge system

Energy Generation Methods

Although the most common way of producing electricity is still through the combustion of fossil fuels, 10% of the electricity in Wales is produced by renewable means, and this percentage is quickly growing.

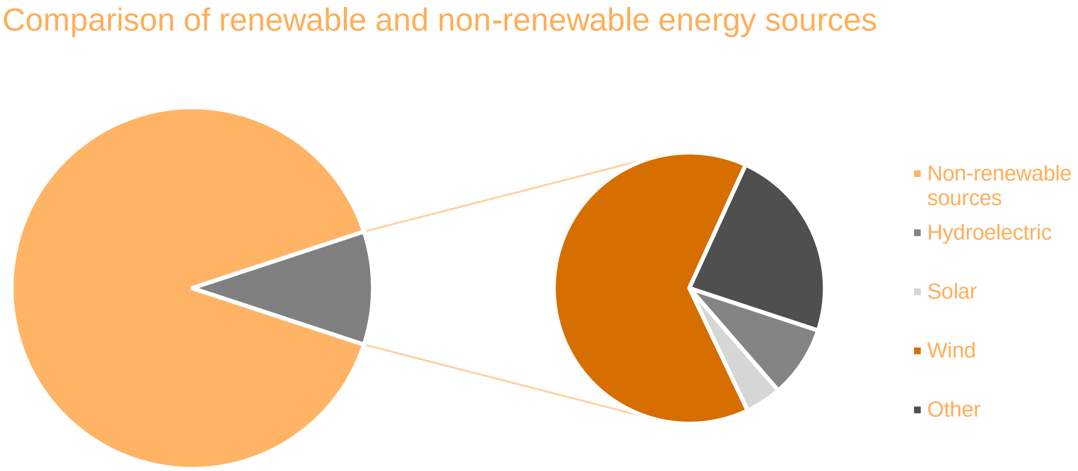


Figure 24 percentage of electricity generated in Wales by source as shown in Energy and Consumption of Wales 2013

Hydro, wind and solar are all ways in which Wales produces clean renewable electricity. Wind is the most prevalent renewable source, as shown in Figure , and continues to grow the most each year as presented by Rhiannon Caunt in 2015.[(3)]

Gwynt y Mor is the second largest offshore wind farm in the World and residing in North Wales. The amount of electricity produced by wind increases each year as shown in Figure 25.

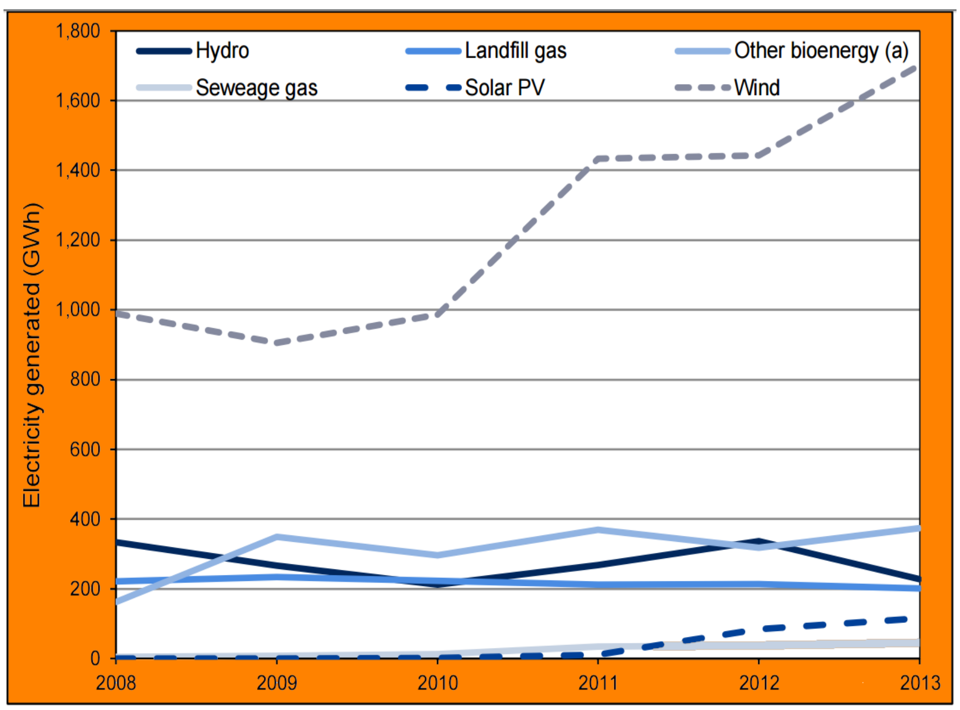


Figure 25 Renewable Generation in Wales, by source (8)

There are also plans for more wind farms to be built, and so the percentage of electricity produced by wind will increase. (1) This means that the overall carbon footprint of Wales would decrease with the use of electrically powered transport.

It is highly likely that tidal power will soon make a major, and growing, contribution to Welsh power generation.

There are a variety of sustainable solutions to ensure sufficient available power for both public transport and local inhabitants. On a rural scale, solar and wind power systems that can provide power for both the charging station and the local inhabitants, directly or via the application of smart grid technology, can be constructed. This would be applicable to both road and rail vehicles, where appropriate.

There are implications of local installations such as solar farms and wind turbines, where local opposition can occur, such as the case of the Llanbadarn Fynydd, Llaithddu, Llanbrynmair, and Carnedd Wen projects, and to re-power the Llandinam wind farm[ix]. However, this is balanced by the obvious environmental and health advantages.

Modular electrification in Wales supports the growth of renewable energy, even more so, when combined with battery storage supports managing electricity generation peaks from renewable sources.

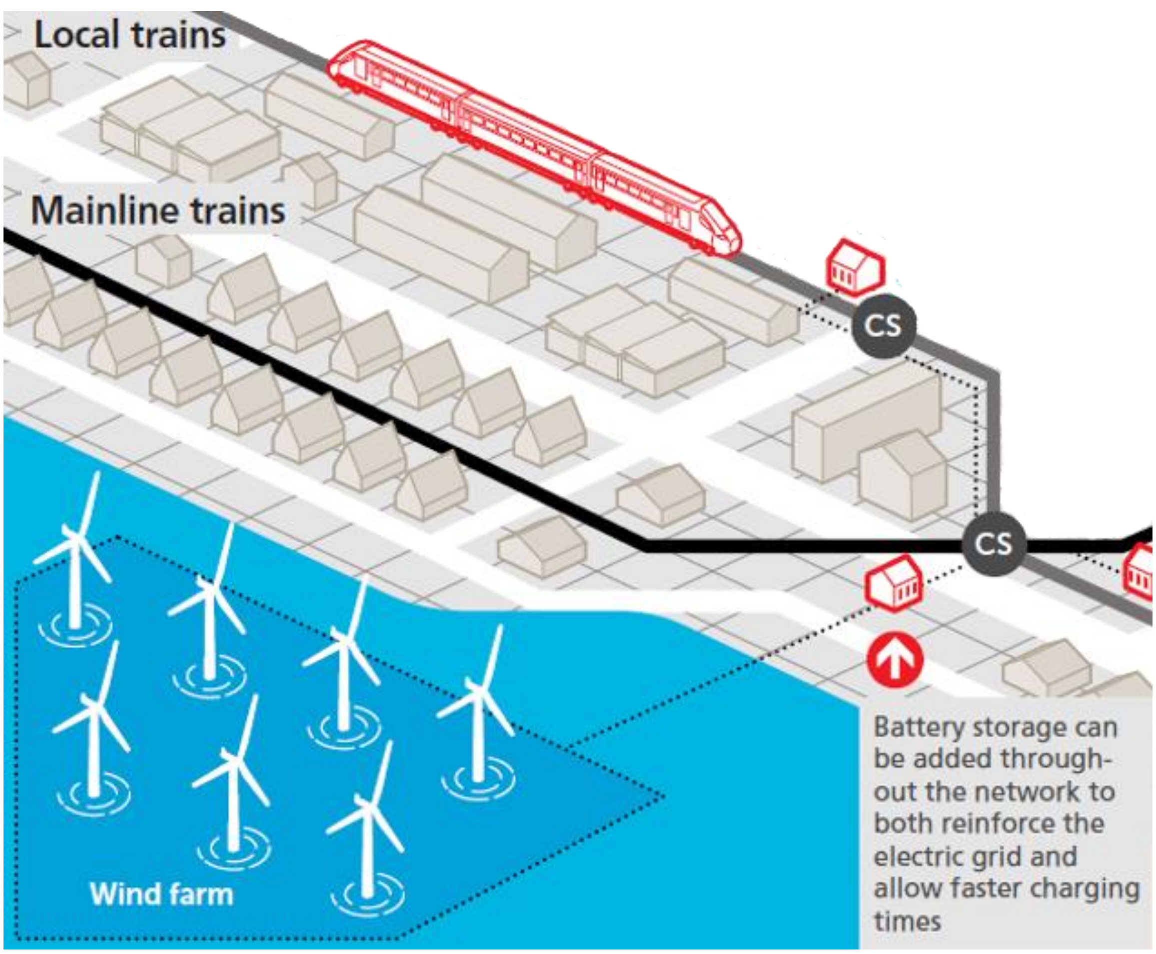


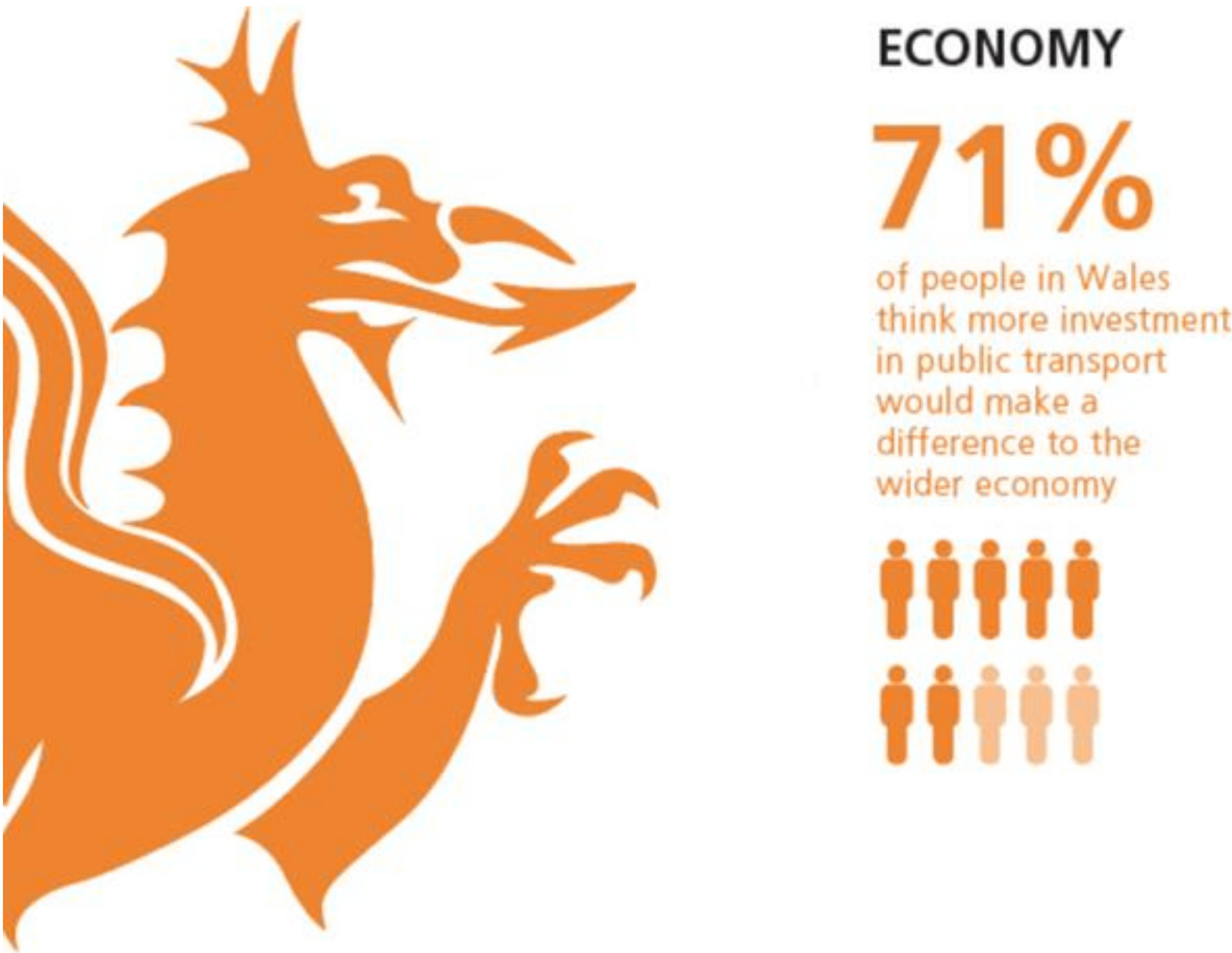
Figure 24 Electricity produced from wind energy can be used to power trains

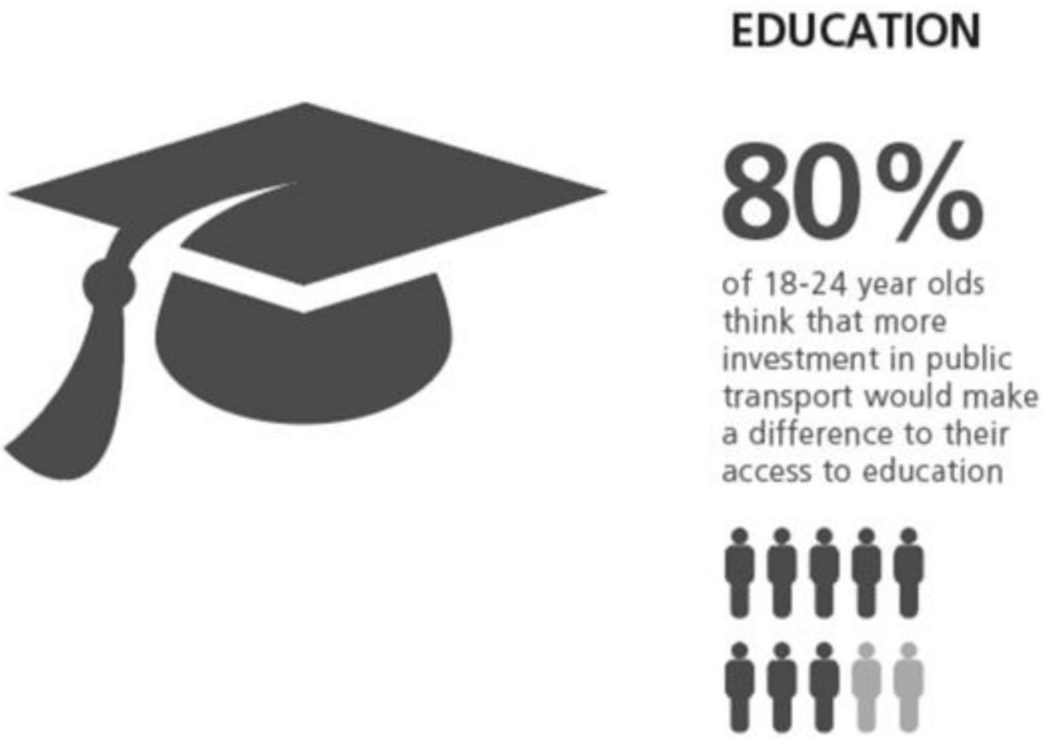
Welsh Opinion on Public Transport

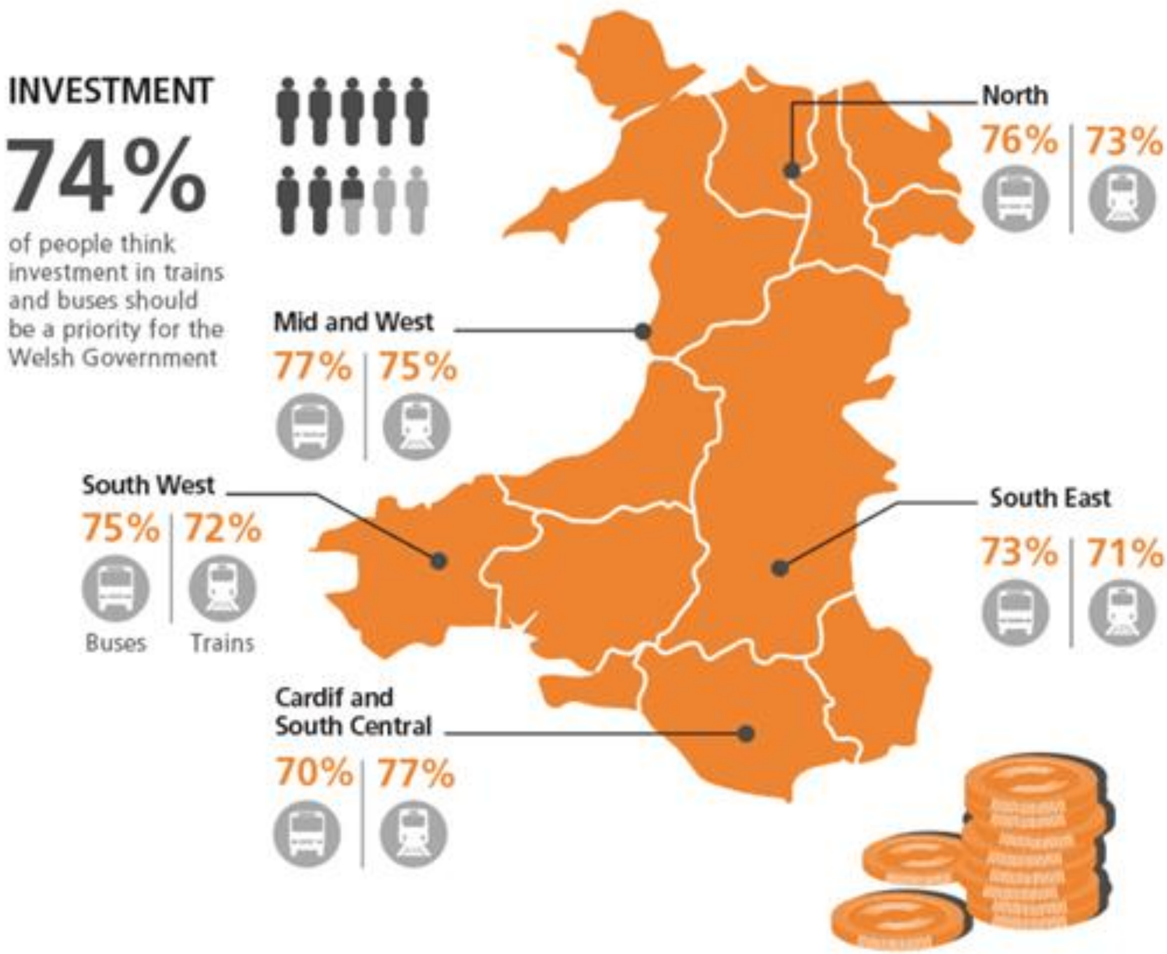
The most important opinion for investment in public transport is that of the users, the Welsh public. To support this white paper, Furrer+Frey undertook a survey in Wales with YouGov. Over 1000 responses from across Wales were recorded[x]. The survey clearly shows the appetite for investment in public transport and the benefits that investment would bring. The survey focused on 7 key areas:

+ Current Satisfaction
+ Job opportunities
+ Investment in Wales
+ Education opportunities
+ Economic Growth
+ Communities
+ Connections

Some significant highlights of the survey are shown below. The full survey results can be found in Appendix 1.




EDUCATION
80%
of 18-24 year olds think that more investment in public transport would make a difference to their access to education


INVESTMENT
74%
of people think investment in trains and buses should be a priority for the Welsh Government
North
76% | 73%
Mid and West
77% | 75%
South West
75% | 72%
Buses
Trains
South East
73% | 71%
Cardif and South Central
70% | 77%

SATISFACTION

48%

Only 48% of people are currently satisfied with public transport regionally. Only 5% are very satisfied in North Wales.

JOBS

70%

of people in Wales think more investment in public transport would create jobs and 80% think it would be easier to access those jobs

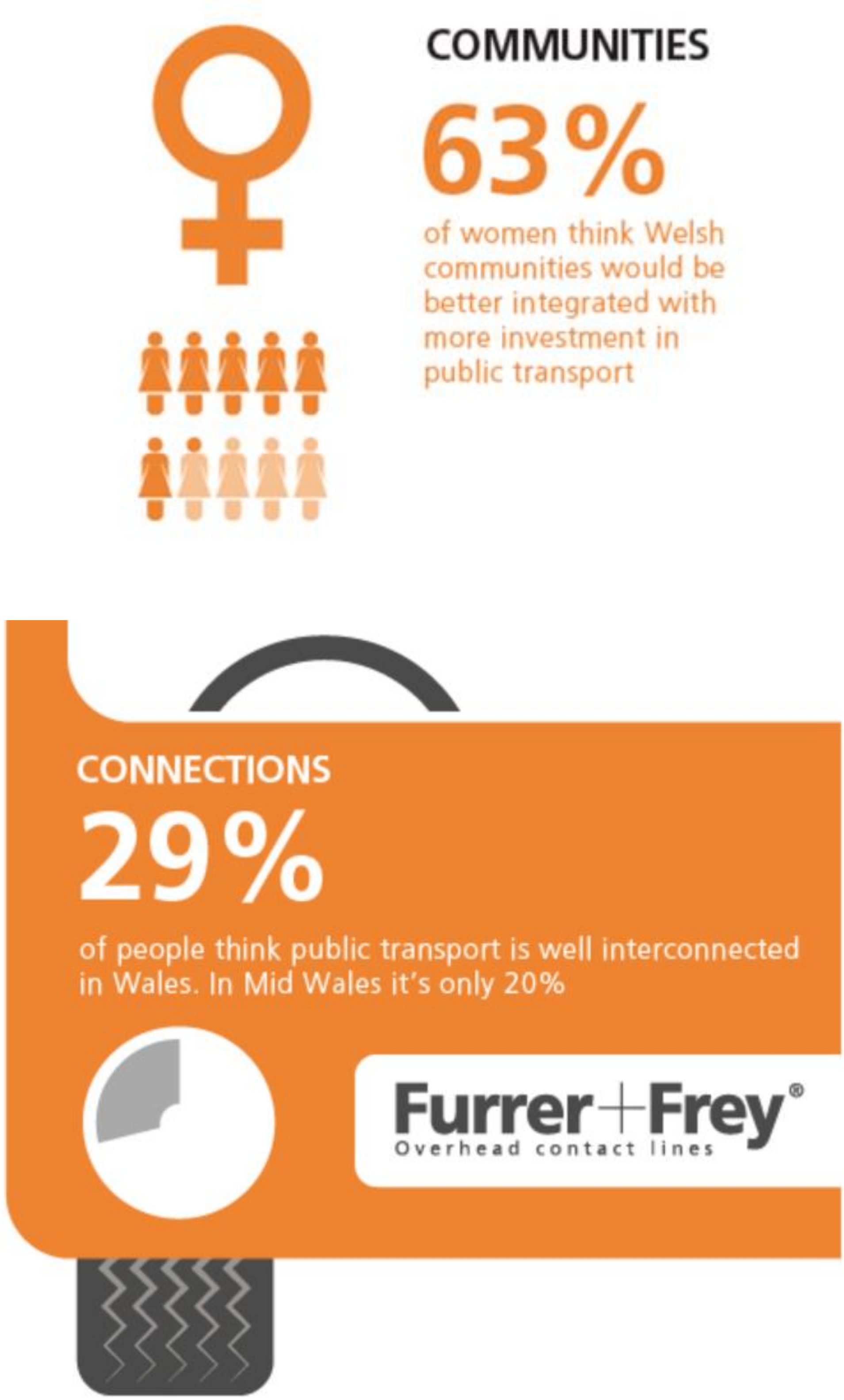


Figure 25 Pictures taken from Furrer+Frey YouGov Survey- January 2017

Positive Impact of Public Transport Investment

Economy

Investing in public transport to increase connectivity attracts investment, and 70% of the Welsh population agree that it will be beneficial, as shown in Figure 26.
Tourism is another sector which can benefit the economy. Improving connectivity of the country will allow the culture and heritage sites to be more accessible to both tourists and locals, increasing touristic revenue.

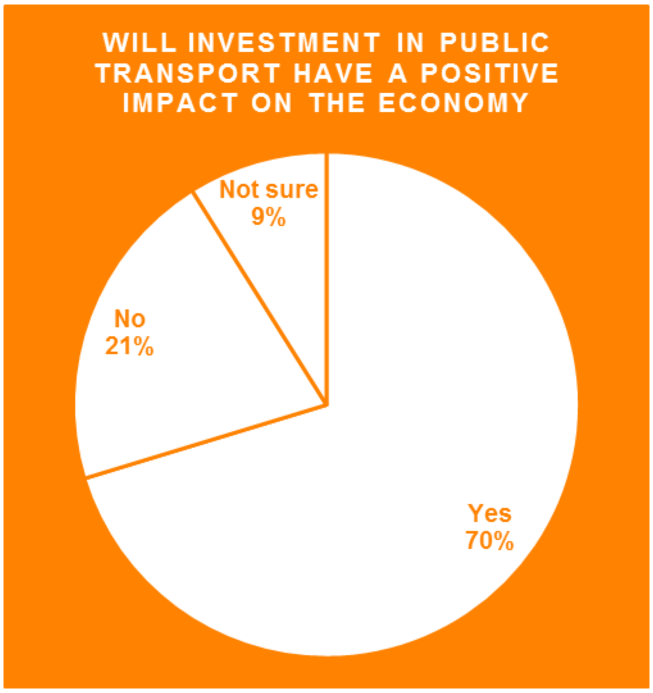


Figure 26 Graph showing the public opinion on whether public transport investment will benefit the economy

In the future, if more students pursue a STEM (Science, Technology, Engineering, Maths) career, there will be a growth in the sectors concerned which will cause large businesses in Wales to grow and attract more developers. If the transport system is well developed across the whole of the country, business developments will not be restricted to the more urbanised areas.

Education

Education is vital to ensure that the younger generations can thrive and achieve their full potential. The National Survey carried out in 2011 states that only 66 of every 100 people are satisfied with the education in Wales, leaving a lot of room for improvement.

Figure 27 Taken from National Survey - 2011

The opinion of 18-24 year olds is of key importance when considering impacts on education due to them being at the stage of choosing whether to carry on with higher education. Over half are unsatisfied with their public transport system and 80% find that the investment would improve access to education, which younger generations would need to reach their full potential.

The transport industry heavily relies on engineering. The rolling stock, traction system and stations all involve aspects of engineering which require maintenance. This increases the number of work-based learning opportunities available to students interested in STEM career paths.

Such opportunities may also promote an engineering orientated career path to students who may not have previously considered it due to lack of exposure to STEM, Culture and Connectivity of Communities

It has been recognised that transport plays a big role in the everyday lives of people as it influences what they do and where they go, and so people living in rural areas should have equal opportunities to those in more urbanised areas. 52% of those in Mid and West Wales, which mainly consists of rural areas, are not satisfied with the public transport system as shown in Figure 29.

The survey also tells that 68% believe that public transport improvements will provide better integration amongst communities. Connectivity between communities enables the Welsh culture to be shared and continue to thrive.

The National Eisteddfod of Wales is an example of a cultural event that will benefit from an extensive public transport system. Events like this are a good opportunity for all the residents of Wales to gather and enjoy their culture.

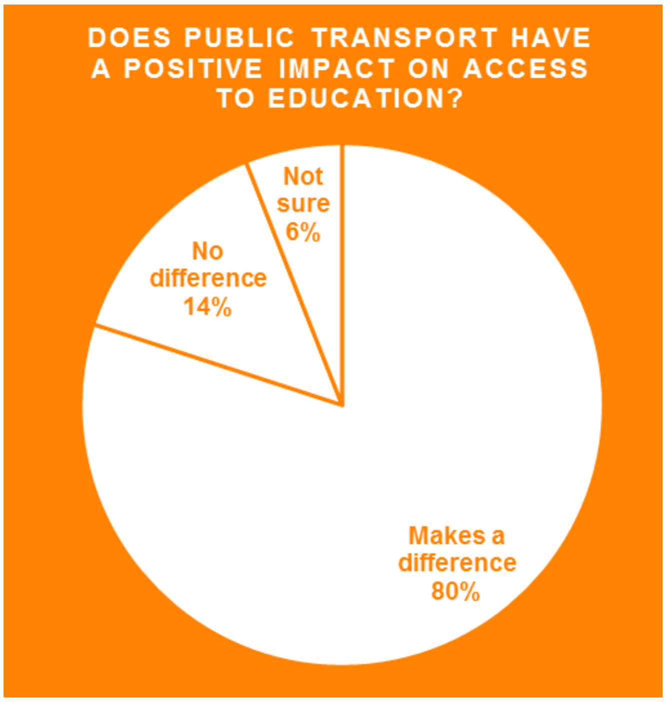


Figure 28 Graph to show the opinion of 18-24 year olds that think investing in the public transport system will improve access to education

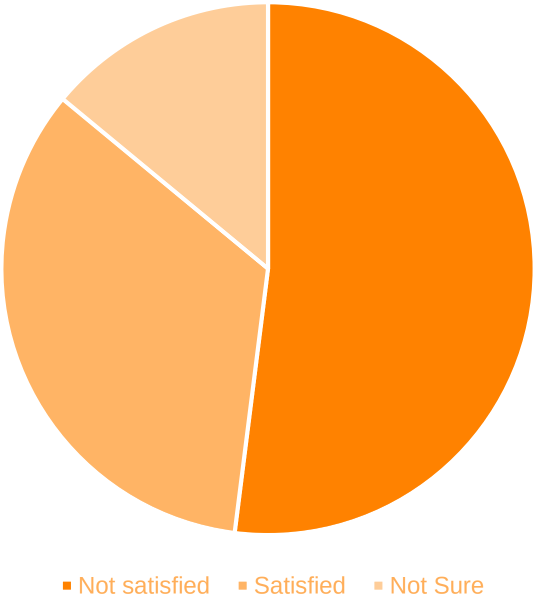


Figure 29 Graph showing the percentages of how satisfied people living in mid and West Wales are with their public transport system.

Health and Environment

Figure 30: Taken from National Survey 2011

Public transport is a form of active transport. It involves physical exercise as people switch between different modes. This can promote a healthier lifestyle involving more activity.

The increased use of public transport results in a decline of private car use; the production of harmful emissions, such as carbon monoxide, reduces. The health of the Welsh people improves in the long term due to less air pollution being breathed in. The natural environment and biodiversity in Wales all benefit from this, especially in conurbations where a well-connected transport network is essential.

The above data shows that currently there is a poor public perception of the current offering of public transport and that public transport is poorly connected. There is also a clear appetite for investment in public transport and the public in Wales believe that there will be benefits in all key areas, namely: access to jobs and education, increased investment and economic growth as well as better connected communities and environmental and health considerations.

The appendix has a full breakdown of results by region.

Greener Transport Alternatives

The Electrification Business Case

With plans of extending the existing public transport system, electrification is a suitable path for Wales to consider whilst keeping the Future Generations Act in mind. Fossil fuels are depleting and will not be a reliable source in the future. Mass development of the current diesel system will cause a surge in the production of emissions. To contain this, electrically powered systems should be considered.

Electrically powered trains allow energy-efficient travel over longer distances. Without the need to carry their fuel source with them, they can accelerate and decelerate faster than diesel systems, allowing more time travelling at their top speed and therefore decreasing journey times. The vehicles are cleaner and will produce less noise pollution whilst connecting the country (2).

The business case for both road and rail electrification has these common main elements:

+ Segregating public transport costs from the direct effect of fossil fuel costs
+ Lowering operating costs, due to the direct effect of enhanced reliability
+ Reduction of the costs to health services due to the reduction of diesel emissions
+ Increase in ridership, and related revenues, due to an improved passenger experience and reduced travel times
+ Decrease in the environmental and economic impact of cars

Model characteristics[xi]	Bus	Maximum Bus Priority	Busway	Tram	Light rail	Heavy rail
Maximum capacity /passengers per hour	2,500	4,000	6,000	12,000	18,000	30,000 +
Capital cost per route km/£m (2009)	<1	1 to 2	1 to 20	15 to 20	10 to 45	45 to 250
Operating cost per passenger place km/pence (2009)	3.8 to 8.8	2.5 to 5.8	2.5 to 5	1 to 2.1	1 to 1.4	1.5 to 1.8
Average speed/kmh	10 to 14	14 to 18	15 to 22	15 to 22	15 to 40	18 to 40
Reliability	Improving	Medium	Good	Medium to Good	Good	Very Good
Space allocation	Mixed running with traffic	Mixed running & separate road lanes	Totally segregated alignment required	Mixed running and on road tram lanes & fully segregated	Largely run on segregated alignments	Totally segregated

Table 1 Taken from an Andrew Adonis Transport paper

Electrification Systems

Currently Wales has no electrified railway lines, no trams in operation, and no trolley buses or any light rail. It also has no electrically powered buses. The North Wales Joint Local Transport Plan 2015, and the Joint Transport Plan for South West Wales 2015-2020 do not discuss road based electrification projects. However, careful selection of electrification systems can reduce costs, and in addition provide significant health benefits by the reduction and potential elimination of atmospheric emissions.

Not every electrification solution requires large capital investment programmes with invasive, large-scale infrastructure. It is not solely a rail solution. It does not require overhead line electrification (OLE) in every case. It is a set of solutions for road and rail, and when used as part of an integrated transport plan, electrification provides a scalable solution that can coexist with and enhance current vehicle investment and delivery strategies. Electrification is a portfolio of solutions that permit scalability, matched to need and budget.

Electrification also offers the opportunity to cost effectively remove the operational carbon footprint of public transport, and eliminate carcinogenic diesel emissions. Electric vehicles have significant advantages over diesel-powered vehicles[xi].

Figure 31: Furrer+Frey BIM model visualisation Great Western

Compared with internal combustion powered vehicles electric vehicles are more reliable and have lower operating costs, as generated electricity is currently a cheaper source than diesel fuel. It also removes a direct connection with fossil fuel costs. This opens up the potential for sustainable sources of power generation, without emissions of any sort, being the source of power for public transport.

There are

- Third Rail Systems
- Conventional Mainline Rail Overhead Line Electrification
- Low-cost electrification solutions with Overhead line
- Tram Systems and Tram-Trains
- Trolley Busses
- Rapid Charge Battery Technology

Figure 32: Photo of Furrer+Frey rapid charge system in Sweden

Conventional Overhead Electrification

Overhead line electrification for heavy rail is the most frequently implemented green upgrade of diesel trains. Electric trains do not need to carry their fuel, so there is a larger capacity compared to a diesel train of the same length. It is proven technology that is used all over the world. (2)

Conventional overhead line electrification for heavy rail is used across England on the West Coast Mainline, East Coast Mainline, Anglia route and most recently, on the Great Western Railway (GWR). The GWR already connects to South Wales, so an extension of the overhead line along this route would be a logical endeavour in connecting the South to the North of Wales. It provides a fast, clean and easy method of travelling across the country.

Overhead conductors for electrification systems consist of a contact wire suspended from a supporting catenary wire. These overhead line conductors are suspended from trackside masts, or portal structures. Supporting structures are typically spaced between 55m and 65m. The precise layout and design of the supporting structures depends on the complexity and speed of the railway. The electric current carrying parts of the equipment are insulated from the structures by means of insulators.

The wires need to be tensioned, so they don't sag and so they maintain the correct position for rolling stock pantographs. 25kV AC substations are located at intervals of up to 50 km, due to their high-power rating (of the order of 15 MVA). These substations draw power via dedicated connections from the National Grid. Trains return current using the rails, which are connected by cables and a network of cables back to the respective substations.

Figure 33: Furrer+Frey Tram System - Bern

The electrification of a currently un-electrified route invariably requires modification to the signalling system, existing trackside systems, infrastructure and interfaces with related railway systems due to electromagnetic effects. There are also civil works related to lines of sight, and dealing with installing OLE near legacy structures.

Further information on OLE systems is given in Appendix 2: Network Rail a Guide to Overhead Electrification 132787-ALB-GUN- EOH-000001 February 2015 Rev 10.

The North Wales Coast Railway route has been considered for electrification to connect it to the future High Speed 2 line which will lie next to the West Coast Mainline that connects London to Crewe, Liverpool and Manchester. The existing connection between Chester and Crewe can be electrified to allow trains from these locations to travel into Wales. If the whole of the North Coast is electrified, the same electrically powered trains can be used.

Electric trains with overhead line electrification traction systems are typically over 35% cheaper to operate than diesels. They require less maintenance and have considerably lower energy costs since electricity is a significantly cheaper fuel than diesel. They are lighter and so do less damage to the track, reducing maintenance costs. Although there are additional costs involved in maintaining electrification infrastructure, these are significantly outweighed by operating cost savings.

Electric trains are generally cheaper to buy than diesel trains, reflected in lease costs which are typically around 20% lower. The engines required to meet modern diesel requirement and standards are likely to be heavier, larger and more complicated as a result of the emissions control technology required.[xii]

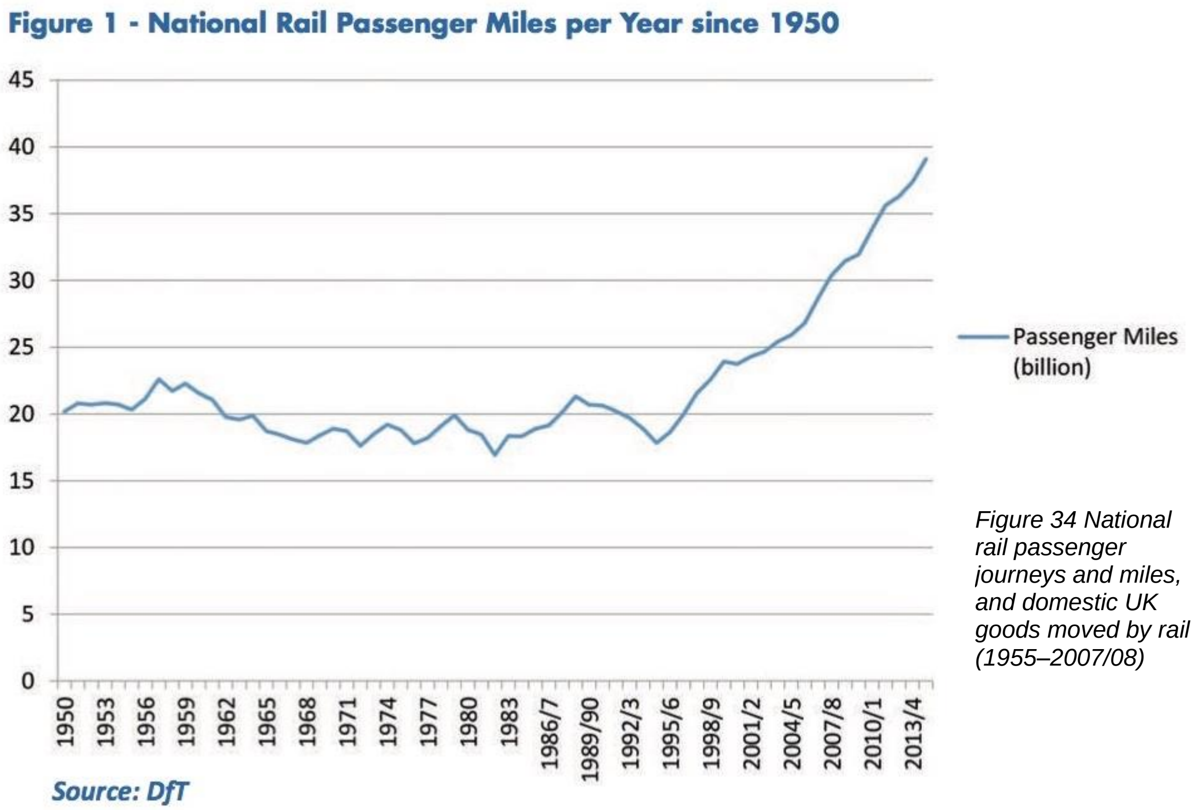


Figure 34 National rail passenger journeys and miles, and domestic UK goods moved by rail (1955–2007/08)

Electric trains also tend to have higher acceleration profiles thus decreasing journey times, and have lower noise and vibration levels compared to diesel trains. Electric trains generally perform better than equivalent diesel vehicles even based on the current fossil fuel/nuclear/sustainable electricity generation mix.

Wales' wealth of current and potential carbon neutral sustainable power offers the realistic potential to eliminate the carbon footprint of public transport. Typically, an electric train emits 20–35% less carbon per passenger mile than a diesel train on the current generation mix. This advantage will increase over time, as the power generation mix becomes less carbon intensive.

The roll-out of regenerative braking enables electric trains to re-use the energy that would otherwise have been lost when braking, by converting the energy of motion back into electricity. Electric trains have zero emissions at the point of use, which is of particular benefit for air quality in pollution 'hot-spots' such as city centres and mainline stations. Electrification reduces rail's reliance on imported diesel fuel. Electric trains are quieter than diesel trains, and virtually silent when waiting at stations.

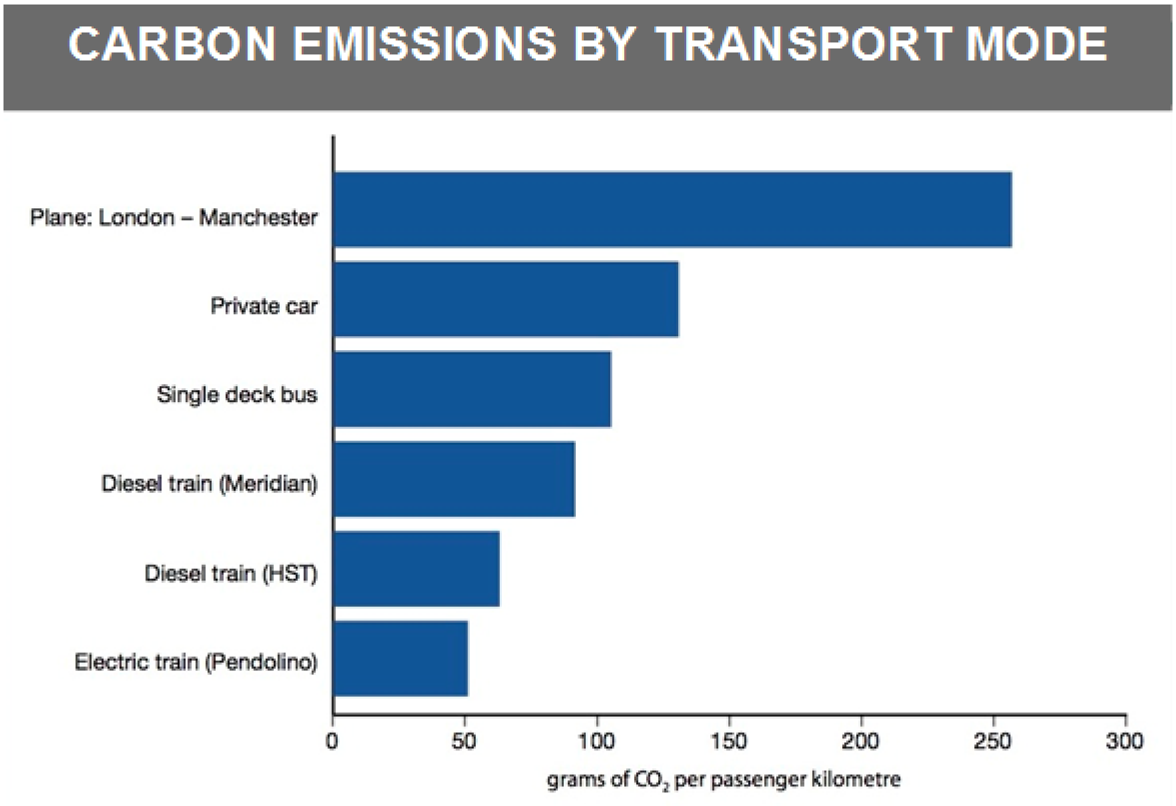
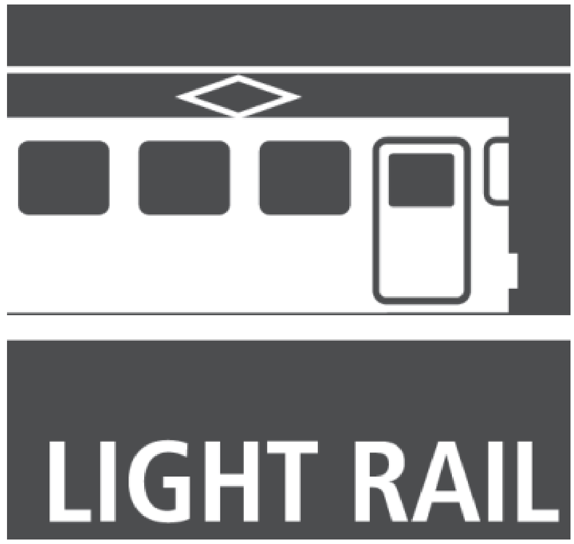


Figure 35 Chart comparing the relative carbon performance of different modes of transport, assuming average load factors.

Low Cost Electrification

Low-cost electrification solutions are a cheaper alternative to conventional overhead line. The concept is suitable for lines with slower line speeds such as light rail systems and branch lines.



According to the PTEG (Passenger Transport Executive Group) 2005 some of the main advantages of Light Rail include:

+ Ability to penetrate town and city centres with permanent, visible and acceptable infrastructure
+ Delivery of predictable, regular and fast journey times, providing a high capacity service on simple and easily understood routes
+ High level of reliability due to segregation from other traffic, priority at junctions and contractual incentives to operators
+ Accessible, well equipped and visible stops
+ A high ride quality throughout the entire journey
+ Effective integration with new developments and park and ride facilities
+ Opportunities to renew both the fabric of the urban areas it serves, and the image of those areas
+ Permanence of infrastructure, vehicles and operations, creating confidence amongst individuals and business to make long term locational decisions that produce long-term patronage growth

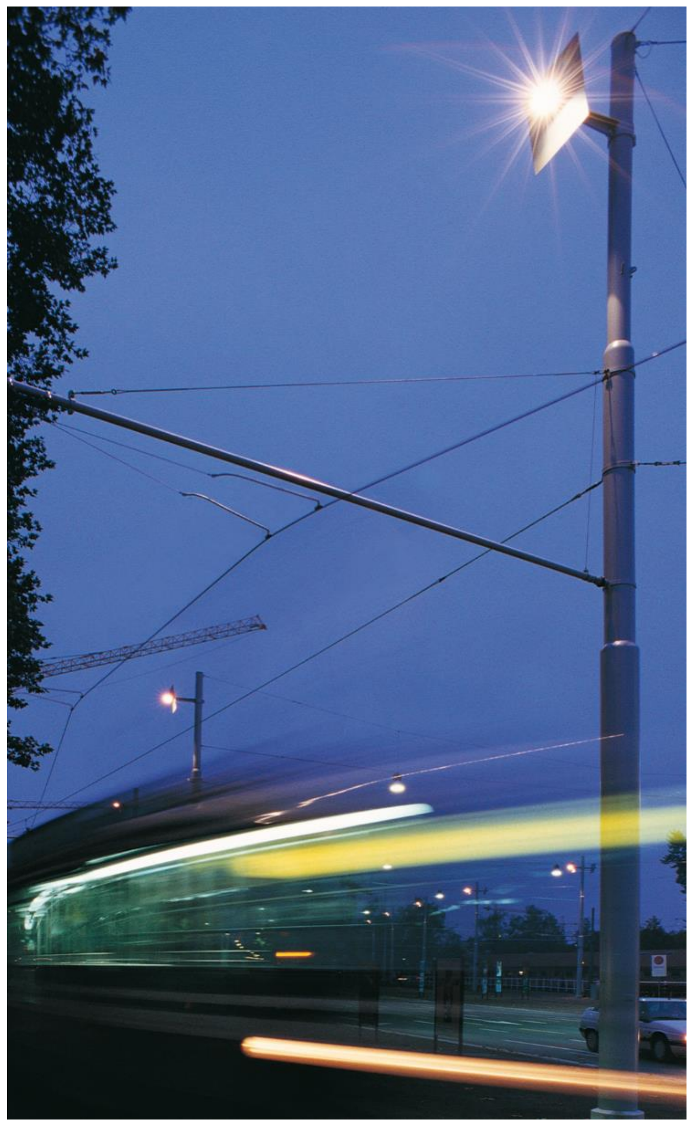


Figure 36 Photo Furrer+Frey designed system, Bern Switzerland

Light Rail systems use lightweight electrification solutions compared with mainline or 'heavy rail', light rail vehicles that operate at lower speeds. However, light rail and tram vehicles have higher rates of acceleration and shorter stopping distances. These systems are usually used in urban environments, offering high frequency services between closely spaced stations.

Often light rail systems use relatively low voltage DC traction power systems, usually in the form of a twin trolley wire overhead contact system. Many UK systems use 750V DC, supplied by substations drawing on the 33kV AC electricity supply distribution system. Again, the current is returned to the substation via the rails. Substations are required to be closer together compared to 25kV Overhead Line.

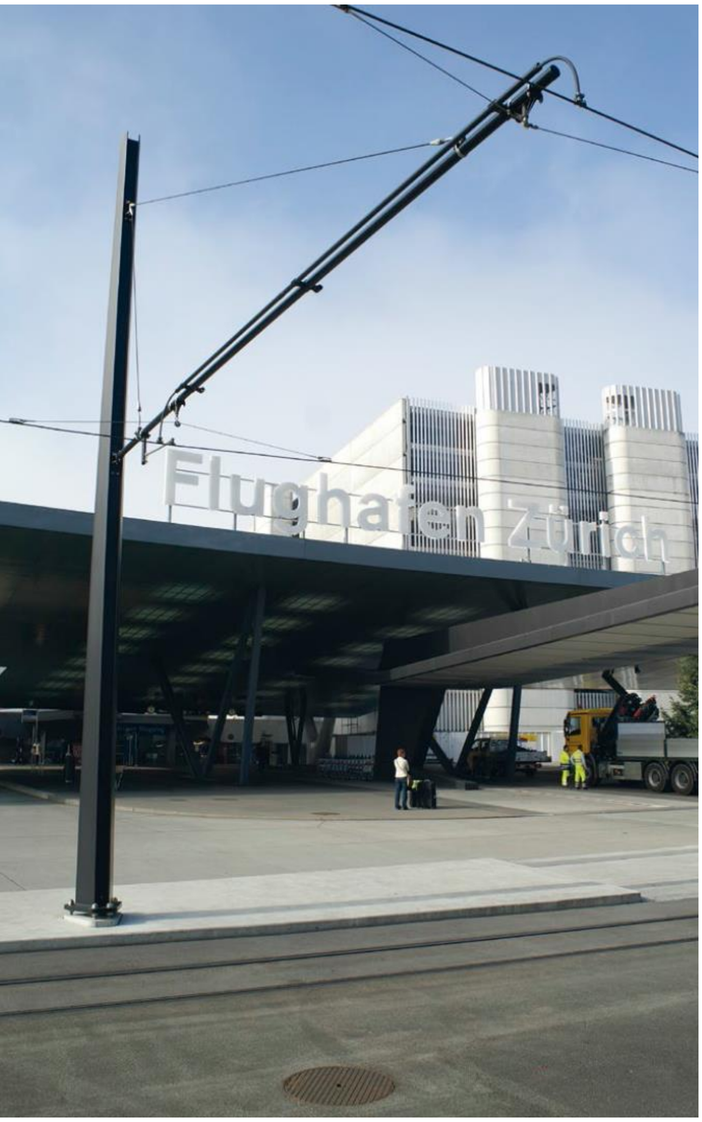


Figure 37: Furrer+Frey System Zurich Airport

Simpler support mast designs (traction pole) are used and designed for reduced visual impact. Twin track areas that have a sufficiently wide trackbed can have one pole supporting the OLE for both tracks.

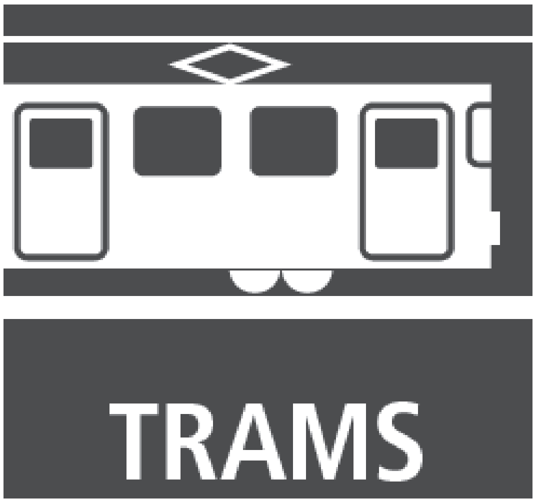
Light Rail (Metro) systems can be operated on segregated permanent ways in the same way as mainline railways. The Tyne and Wear Metro runs on former British Rail tracks and uses a 1500V DC catenary type overhead line system.

Transport for London have identified the following characteristics of the main public transport modes: capacity, capital cost, operating cost, average speed, reliability, road space allocation and land use integration. TfL acknowledged that bus based rapid transit and light rail have an important role to play in urban public transport where full segregation for an alignment is not required (or always available) and shared running with traffic management is feasible.

The Welsh Transport Authority could choose to extend electrification onto branch lines from the main-line electrified arterial route. This would enable a fully integrated system within Cardiff that flows out to the rest of South of Wales from Cardiff. A fully electrified railway means that you do not need to switch between methods of traction. [(4)]

The same approach could also be beneficial for Holyhead, part of the Isle of Anglesey, as it is the start of the North Wales Coast Railway which can potentially be connected to High Speed 2 (HS2) from Chester to Crewe. Since the Holyhead to Chester line is of low usage, a low-cost electrification scheme would gain the benefits of a fully electrified line, without incurring the huge costs associated with an expensive high speed system. (3)

Figure 38 Furrer+Frey system Switzerland



Trams

Tram electrification systems are similar to low cost electrification systems and light rail systems. A tram can have around 4 carriages meaning it has a larger capacity than buses. Routes are partially on the road, providing the potential for integration with the bus system. They can also operate away from the streets so trams do not get caught in congested areas, allowing accurate timetabling and providing a frequent and reliable service. This can make trams more convenient than buses and trains when travelling a short distance from home.

Trams have proven to be successful in areas across the UK such as Edinburgh, London Tramlink, Birmingham, Manchester, Sheffield, Nottingham and Blackpool.

Figure 41: Furrer+Frey system Bern

Tram-Train Systems

A hybrid of light rail systems is used on Tram-Train Systems. These are vehicles that can run on the mainline, light rail and tramlines, and are considered interurban systems. They need to operate using multiple electrification systems, and have to be built, if running on the mainline, to the same regulations that govern mainline stock. Currently only one system is being built, between Rotherham and Sheffield.

Trolley Buses

These electrically powered vehicles usually use 600V DC twin wires, but run on rubber wheels, without tracks. One of the twin wires is used to return the current to the substation. These are now considered legacy systems and new electric buses are normally battery powered.

Rapid Charge Battery Technology

Battery powered public transport has seen huge growth in the past 5 years. Analysis financed through European Union supported research shows that electric battery buses are preferential to internal combustion engine powered vehicles[xiii].

The principle of rapid charge technology is simple: a recharging station connects with the vehicle, rapidly charges the on-board battery pack, which then disconnects, and the vehicle moves off. The spacing of the recharging stations, and the storage capacity, and weight of the battery pack is optimised for the operational use of the vehicle. Thus rail, tram and bus can be accommodated.

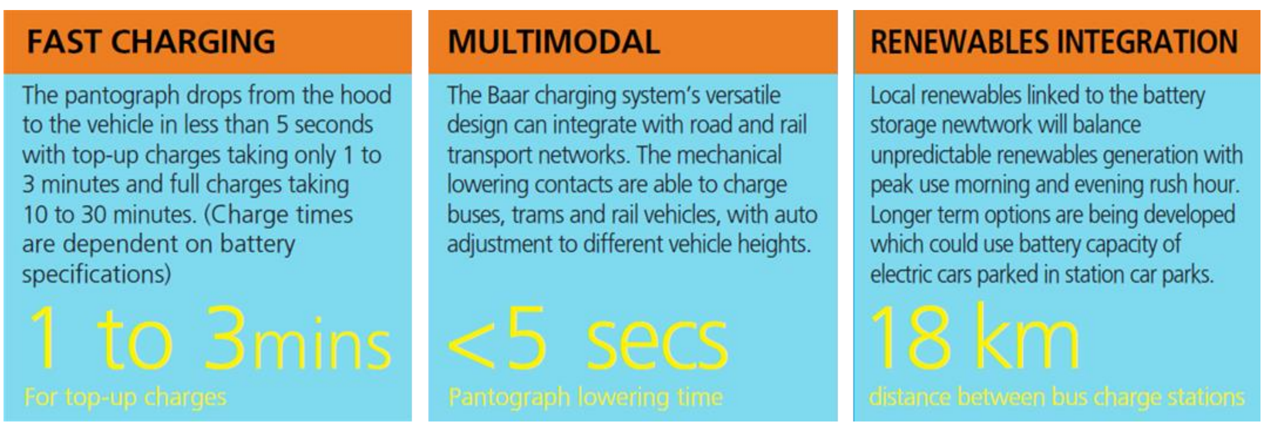
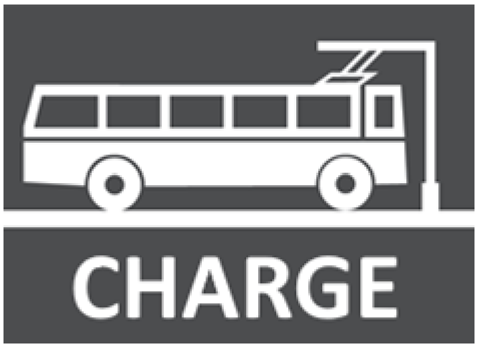


Figure 42 Chart from Furrer+Frey infographic 2016



Rapid Charge is an innovative method of powering buses and trams that has been implemented across the world. The Zero Emission Urban Bus System (ZeEUS) project in the EU is promoting the uptake of innovative electric bus technologies.

Research is taking place across 10 countries including France, Italy, Sweden and Spain. Bus stops are equipped with a charging station so that a quick top-up charge can be administered whilst commuters are alighting from the bus. This brief battery boost keeps the service running as normal without any additional disruption.

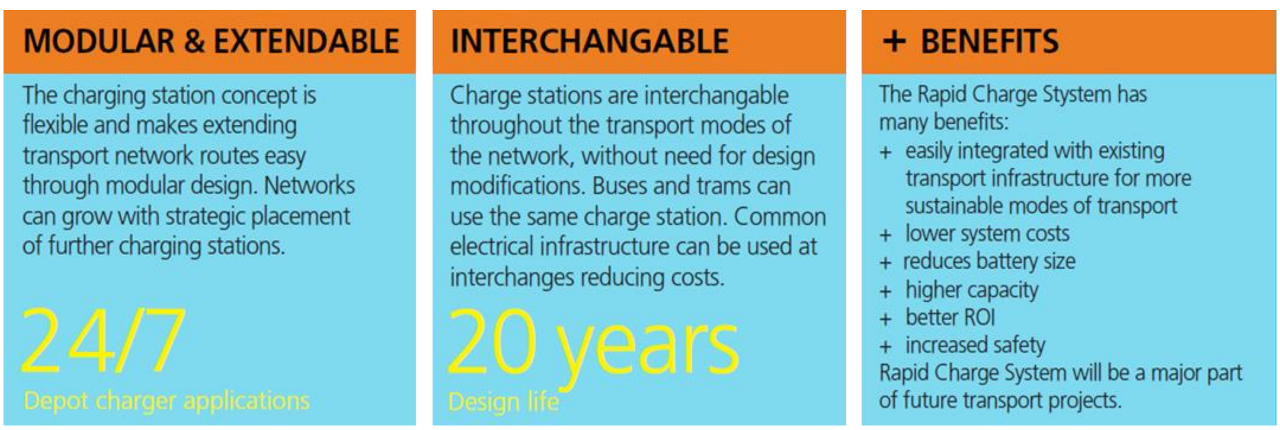


Figure 43 Chart from Furrer+Frey Infographic 2016

Third Rail Systems

Figure 44: Manchester - Bury – prior to its conversion to overhead line

Traditional mainline electrification in the UK falls into two classifications: 600/750V DC conductor rail or 25kV AC overhead line systems.

DfT policy is that no further DC conductor rail systems be used, except where there is an economic case for extending an existing 750V DC electrified system. Legacy system stock also has to be convertible to 25kV AC overhead line systems.

Third rail systems offered a robust and unobtrusive means of power delivery, and avoided significant permanent way modifications in tunnels, and are still the predominant Electromotive Unit (EMU) stock in the southeast of England. However overhead line electrification (OLE) is more efficient power delivery and superior dynamic current collection characteristics, and allows higher operating speeds.

Road Use

Rapid charging also lends itself to enhancing bus rapid transit and guided bus schemes, such as metro Swansea. Conversion can be done without ceasing operations, and diesel and electric vehicles can be operated at the same time

Initially the vehicle is charged at the depot. A top-up charge is administered whilst commuters are alighting from the bus. This brief battery boost is done using a pantograph-style charging pad that connects to the top of the vehicle. Rapid charging is just that, rapid:

The footprint is of a charging station is of the order of a half-a-square-metre. Rapid charge is not only limited to public transport vehicles. Stations can charge any vehicle that is fitted with the respective rapid charge technology.

A third type of charging location is a "mini-charging depot". These can be located at a strategic location in a city near one or more bus terminals. A mini charging depot has several fast chargers, is located in an off-street location near several bus lines, and has good connections to the grid. Large battery buses can "top-up" a few times per day during scheduled charging stops during lull periods in passenger traffic. This type of infrastructure can help to lower the carbon footprint of other services such as rubbish and recycling collection.

Rapid charge enabled rubbish collection vehicles can use the same charging stations as the buses, during off-peak hours. Road freight or long haulage vehicles, as well as urban vehicles can also adopt this technology. In all cases, it can eliminate the need for diesel engines and their emissions.

Figure 45 Alternative Rapid Charge Solutions – Furrer+Frey / Opbrid visualisations

Figure 46 Furrer+frey impression of multimodal rapid charge stations

Rapid Charge Stations also provide a perception of permanence particularly to bus routes, which do not have the same level of fixed infrastructure as trams and trains. Studies have shown that increased fixed infrastructure makes the public more likely to use buses and improves the public perception of buses[xiv].

Figure 47: Visualisation from Furrer+Frey of in construction rapid charge in Bern

Rail vehicles

The same technology already in use on the roads can be used for Diesel train replacement or for new trams. The rail vehicle connects with the charging station. The battery draws charge, when the required amount of energy is absorbed the contacts retract and the vehicle moves off.

Instead of the overhead line infrastructure required for traditional Electro Motive Units (EMUs) used for interurban, commuter and rural diagrams, a series of charging stations are spaced along the route. Rolling stock equipped with lithium based battery technology recharge at these stations, and their motors draw their power from those batteries. All major manufacturers have rolling stock designed to run off such systems; some have already been considered for programmes similar to the requirements of the Cardiff Metro and Core Valley lines.

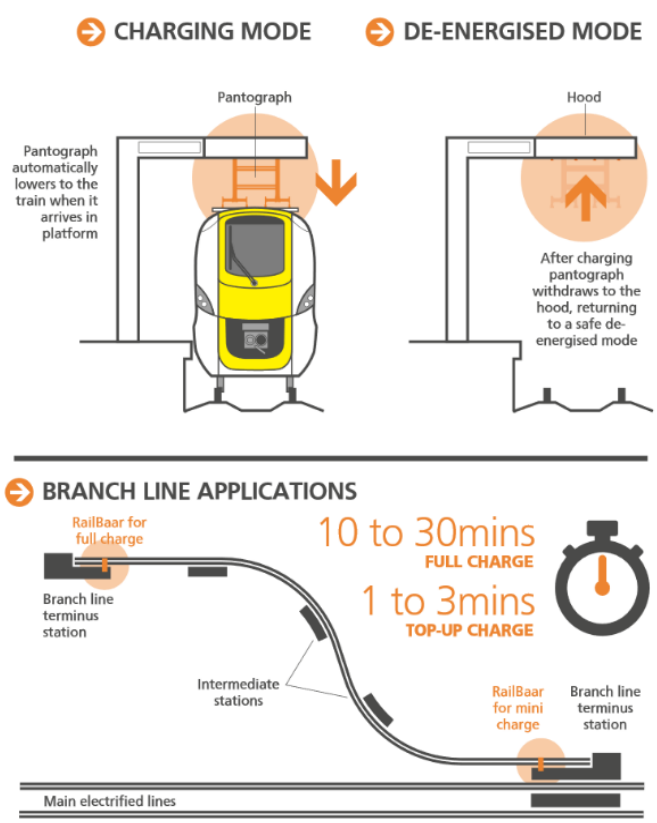


Figure 41 Rapid Charge infographic (Furrer+Frey / Opbrid

Retrofitting diesel stock can also be performed, when the rolling stock has sufficient service life to make it a justifiable return on investment.

Figure 48: Furrer+Frey visualisation Maidenhead station

Our experience in this technology indicate that payback on such a retrofit of a 22m vehicle is in the order of four-years, based on a 340kWh battery pack. A 350kWh gives a 22m vehicle up to a 100km range on a full charge, without the use of intermittent charging. Selecting a cost-effective profile of battery capacity and charging allows this solution to eliminate DMUs, and their harmful emissions.

It also allows cost effective electrification on any rail route, bring the benefit of electrification to the most remote parts of the network, and without the pollution inherent in a fossil fuel burning powertrain, or the expense of OLE.

Modifying modern UK compliant stock with battery packs has already occurred with the Class 379 Independently Powered Electromotive Unit trial. Since that trial the introduction of battery powered trains have been proposed by Network Rail for consideration for the fifteen stations Wrexham to Bidston, Birkenhead, Borderlands Line.

If required, electric bimodal stock can be introduced, where use frequency and passenger numbers, or other route requirements such as heavy freight, support overhead line investment on part of a route. Such stock can recharge and draw power while under the wires, and then switch to internal power and recharge stations when they go beyond the wires. Battery-only rolling stock can still run under the wires, they just won’t have the ability to draw power.

Figure 49: Furrer+Frey visualisation from Kings Cross Station

The potential for employment through electrification

Electrification gives the opportunity to train local resource in the specialised requirements for multimodal electrification installation and maintenance. Should multimodal electrification be introduced into Wales, the potential for further installations within the UK will develop.

Designing, producing, testing, installing and maintaining a system for Wales would require facilities to be developed in Wales, to ensure a cost-effective solution for the Wales. As a by-product, this would give a base to distribute recharge technology from Wales to the rest of the UK.

Traditional OLE solutions would need to be financed in an austerity environment, less expensive solutions that eliminate diesel emission will have a strong potential market, a market that can be supported and supplied by facilities in Wales.

Figure 50: Aerial photo Coleg y Cymoedd

Integration with Bwcabus

The Welsh government has already implemented innovative schemes, such as the Bwcabus which is a perfect solution for rural areas. This service meets the needs of residents with core fixed routes combined with a pre-booking service for maximum flexibility. Despite the success of this project, the locals of the rural areas in central Wales find that the existing transport system does not provide sufficient connectivity (see Figure 51).

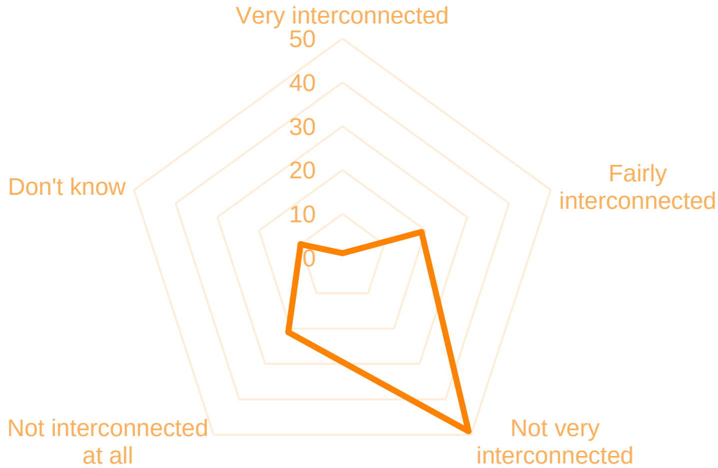


Figure 51 Opinion on connectivity of mid and west Wales

The Bwcabus service could be retro-fitted with rapid charge technology and introduced into other rural areas. This facility already connects to nearby key settlements so other methods of transport, such as rail and the Traws Cymru bus system, can be used for travelling across the country. These new routes have improved access to health and education and work towards greater equality in the community. As well as gaining ministerial praise, the project has received funding to continue operations, and with the inclusion of innovative charging technology, could be an award winning future green initiative.

Holyhead would also benefit from a rapid charge system as the area uses transport for tourism. There is a large port which was used for importing and exporting goods which is now used for docking cruise ships. Coaches usually travel down the jetty to collect and deliver passengers to the town and take them on local tours. If rapid charge enabled coaches are used to transport tourists, the environment would benefit. Rapid charge buses can also run into the town and near to attractions such as the Holyhead Maritime museum so that tourists can explore the island with ease.

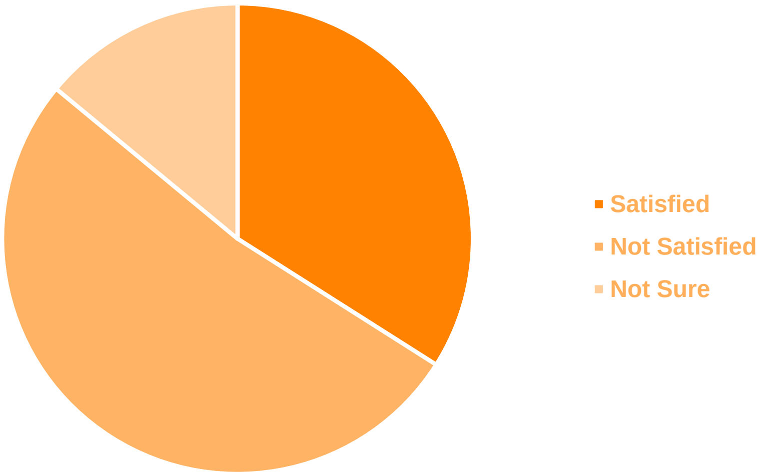


Figure 52 Graph to show how satisfied with their public transport network people in Mid and West Wales are

Figure 53: Visualisation of Bwcabus with rapid charge station

Multimodal Solutions for Cardiff

Cardiff is an example of an area that would benefit from the use of rapid charge trains and buses. With the increased use of public transport, the use of private cars will decrease and traffic flow on the roads of Cardiff will improve. In order to make the opportunities within Wales equally accessible to everyone, Cardiff needs a public transport system that flows smoothly and connects to the rest of the country. The use of a multimodal system, using rapid charge buses and trains, can enable this.

A high frequency service provides a 'turn up and go' experience for passengers using a system designed for speed and agility. A smooth flowing system that is well integrated within the city, will extend out and allow the rest of the country to be better connected.

Figure 54: Furrer+Frey Tramway/Light Rail System Bern

Power distribution and generation models

Charging road or rail vehicles takes significant amounts of grid power. For example, 50 buses each charging overnight at 60kW requires 3MW of grid capacity. Distributed curbside opportunity chargers can require 300-500kW at bus route end terminals.

Charging locations need to be coordinated with the energy provider so that sufficient grid capacity is available at both depots and opportunity charging locations. However, this should be considered in context: the power required to recharge 50 buses is the output of one standard offshore wind turbine[xv], or less than 10,000m^2 of solar farm (less than seven rugby pitches), with power left over[xvi].

There are a variety of sustainable solutions to ensure sufficient available power. On a rural scale, solar and wind power systems that can provide power for both the charging station and the local inhabitants, directly or via the application of smart grid technology, can be constructed. This would be applicable to both road and rail vehicles, where appropriate.

Furthermore, by combining with local battery storage local renewable resources can be maximised and peaks in demand managed effectively.

Multimodal Transport Upgrade Options

Mode of Transport	Cost	Sustainability	Suitability
Diesel	-High cost; fuel required, slow acceleration elongates journeys Not cost effective	-Emissions are harmful to health and environment -Fossil fuels availability is depleting, not a reliable fuel source for the future	Does not meet sustainability goals.
Rapid Charge	+Saves on fuel +Low system cost	+Modern technology that produces no direct emissions +Uses electricity +Reliable and safe	West Wales, Pembrokeshire and Mid Wales are suitable for a rapid charge Bwcabus service which is ideal for rural areas. Cardiff Metro
Conventional electrification	+Reduces journey times -Expensive to install +Good long term investment	+Electrically powered; no direct emissions +Connects far ends of the country +Attracts development, as the fast movement of freight is enabled. +is interoperable with electrified lines connecting Wales with England	North Wales Coast Railway. North to South
Low Cost Electrification	+Low cost +reduces journey times of light rail systems +Cost effective in the long term	+Quicker accelerations, faster journeys +Electrically powered +Modernising low usage routes and low speed systems +Removes pressure off the road thus reducing congestion	Holyhead to Chester Cardiff Metro
Trams	+Low cost electrification	+Reliable service +More capacity than buses, can improve connections within a town +Electrically powered +Removes pressure from the road thus reducing congestion	Not a current interest of the public of Wales Pembrokeshire?

Table 2 Synopsis Table - Furrer+Frey

Conclusion

Rapid Charge, conventional and low-cost electrification systems suit the direction in which Wales is moving with its plans for sustainable development of transport as shown below. It benefits the environment by reducing private car use and using electricity which can be produced from renewable sources.

Environment

- **Reducing emissions**
- **Reducing impact on biodiversity of Wales**
- **Increasing renewable sources for electricity production**
- **Decreasing carbon footprint**
- **Re-using existing rolling stock**

Social

- **Improving health**
- **Improving education**
- **Increasing job opportunities**
- **Promoting leisure attractions**

Economy

- **Saving money**
- **Increasing public transport use**
- **Increasing employment opportunities**
- **Increasing tourism**
- **Increasing freight opportunities**
- **Attracting business**
- **Attracting development and funding for infrastructure**

An extensive transport system improves the access to jobs, education, health facilities and leisure attractions across the country. Furthermore, it will have positive effects on health, and equality in accessing opportunities across Wales. It allows sustainable connectivity throughout the country and internationally which will allow the country to flourish as tourists and developers are attracted. It is the best way to ensure that Wales will develop sustainably.

Appendix 1 – Full Survey Results

Survey carried out between 10th and 13th January 2017 in conjunction with YouGov and Furrer+Frey, with 1,103 Welsh adult respondents.

		Gender		Age				Region				
	Total	Male	Female	18-24	25-39	40-59	60+	Mid and West	North	Cardiff and South Central	South East	South West
Weighted Sample	**1103**	533	570	132	236	372	363	211	228	246	228	190
Unweighted Sample	1103	500	603	92	207	381	423	228	244	222	225	184
	%	%	%	%	%	%	%	%	%	%	%	%
How much difference, if any, do you think investing in public transport in Wales would make to each of the following areas?												
The Welsh economy in general												
A great deal of difference	**28**	28	28	22	28	31	27	26	29	33	29	22
A fair amount of difference	**43**	44	41	53	39	39	44	43	43	39	43	45
TOTAL WOULD MAKE A DIFFERENCE	**71**	**72**	**69**	**75**	**67**	**70**	**71**	**69**	**72**	**72**	**72**	**67**
Not a lot of difference	**16**	18	15	15	17	15	18	17	14	18	14	18
No difference at all	**4**	5	4	3	6	5	3	5	2	2	7	6
TOTAL WOULD NOT MAKE A DIFFERENCE	**21**	**23**	**19**	**18**	**23**	**20**	**21**	**22**	**17**	**20**	**21**	**24**
Don't know	**9**	5	12	7	11	10	8	9	12	8	7	9
Access to places of education												
A great deal of difference	**30**	27	33	31	29	30	31	36	31	29	31	24
A fair amount of difference	**43**	46	40	49	43	42	42	38	45	43	45	43
TOTAL WOULD MAKE A DIFFERENCE	**73**	**73**	**73**	**80**	**72**	**72**	**72**	**74**	**76**	**72**	**75**	**67**
Not a lot of difference	**14**	16	12	11	13	14	16	14	12	17	13	15
No difference at all	**5**	6	4	4	6	5	5	6	3	4	6	6
TOTAL WOULD NOT MAKE A DIFFERENCE	**19**	**21**	**17**	**14**	**18**	**19**	**21**	**20**	**15**	**21**	**19**	**21**
Don't know	**8**	5	11	6	9	9	7	6	9	7	6	12
Access to jobs												
A great deal of difference	**42**	39	46	37	46	42	42	48	42	41	48	32
A fair amount of difference	**38**	42	34	46	34	36	40	33	38	40	35	45
TOTAL WOULD MAKE A DIFFERENCE	**80**	**81**	**80**	**83**	**80**	**79**	**81**	**82**	**80**	**80**	**83**	**76**
Not a lot of difference	**10**	12	8	11	9	10	9	7	10	11	9	12
No difference at all	**4**	4	4	2	4	5	4	7	2	3	4	4
TOTAL WOULD NOT MAKE A DIFFERENCE	**14**	**16**	**12**	**13**	**13**	**15**	**13**	**14**	**12**	**13**	**13**	**17**
Don't know	**6**	3	9	4	7	6	6	5	8	7	4	7
How much difference, if any, do you think investing in public transport in Wales would make to each of the following areas?												
Better integration amongst communities												
A great deal of difference	**22**	23	22	14	18	25	26	28	24	24	20	15
A fair amount of difference	**37**	32	41	46	36	33	38	40	36	37	40	32
TOTAL WOULD MAKE A DIFFERENCE	**59**	**55**	**63**	**60**	**54**	**58**	**63**	**68**	**59**	**61**	**60**	**47**
Not a lot of difference	**22**	25	20	22	24	20	23	18	22	22	20	29
No difference at all	**9**	12	6	11	9	11	7	8	6	9	12	11
TOTAL WOULD NOT MAKE A DIFFERENCE	**31**	**37**	**26**	**33**	**33**	**31**	**30**	**26**	**28**	**31**	**32**	**40**
Don't know	**10**	8	11	8	13	11	7	6	13	8	8	13
Creating jobs												
A great deal of difference	**30**	28	31	25	30	31	30	28	27	33	30	31
A fair amount of difference	**41**	41	40	50	42	37	40	41	46	40	40	35
TOTAL WOULD MAKE A DIFFERENCE	**70**	**69**	**72**	**75**	**72**	**68**	**70**	**68**	**73**	**73**	**70**	**66**
Not a lot of difference	**18**	21	14	19	13	19	18	17	15	16	20	21
No difference at all	**4**	5	3	1	6	5	3	6	3	4	3	4
TOTAL WOULD NOT MAKE A DIFFERENCE	**22**	**26**	**17**	**20**	**19**	**24**	**22**	**24**	**17**	**20**	**23**	**25**
Don't know	**8**	5	11	5	10	8	9	8	10	8	7	9
Thinking about your local area, how satisfied, if at all, are you with the public transport service?												
Very satisfied	**8**	6	9	8	5	4	12	6	5	11	7	8
Fairly satisfied	**41**	44	38	38	37	43	42	28	40	47	42	45
TOTAL SATISFIED	**48**	**50**	**46**	**46**	**42**	**47**	**54**	**34**	**46**	**58**	**49**	**53**
Not very satisfied	**28**	27	29	42	36	24	21	28	30	27	30	24
Not satisfied at all	**13**	12	14	9	9	15	15	24	13	8	10	11
TOTAL NOT SATISFIED	**41**	**39**	**43**	**51**	**45**	**39**	**36**	**52**	**43**	**35**	**40**	**35**
Don't know	**11**	11	11	3	13	14	10	14	12	7	11	12

	Total	Male	Female	18-24	25-39	40-59	60+	Mid and West	North	Cardiff and South Central	South East	South West
		Gender		Age				Region				
Weighted Sample	**1103**	533	570	132	236	372	363	211	228	246	228	190
Unweighted Sample	1103	500	603	92	207	381	423	228	244	222	225	184
	%	%	%	%	%	%	%	%	%	%	%	%

Thinking more generally about investment in transport and again taking account all the different priorities, please say whether you think investment in each of the following would be a good idea or the wrong priority at this time.

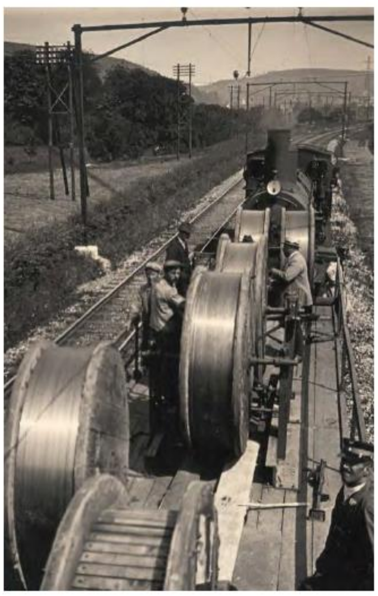
	Total	Male	Female	18-24	25-39	40-59	60+	Mid and West	North	Cardiff and South Central	South East	South West
Buses in Wales												
Good idea	**74**	76	73	80	65	73	79	77	76	70	73	75
Wrong priority	**14**	15	14	13	19	15	10	13	10	20	12	15
Don’t know	**12**	10	14	7	16	11	11	10	14	10	15	10
Trains in Wales												
Good idea	**74**	76	71	82	70	72	75	75	73	77	71	72
Wrong priority	**12**	11	14	11	14	11	12	11	11	10	15	14
Don’t know	**14**	13	15	7	16	17	13	14	17	13	14	14

How interconnected do you think public transport (i.e. trains, trams and buses) are in Wales?

	Total	Male	Female	18-24	25-39	40-59	60+	Mid and West	North	Cardiff and South Central	South East	South West
Very interconnected	**2**	2	2	2	2	0	3	1	2	5	0	0
Fairly interconnected	**27**	27	28	29	33	27	24	19	24	34	28	32
TOTAL INTERCONNECTED	**29**	**28**	**30**	**31**	**35**	**28**	**26**	**20**	**26**	**38**	**29**	**32**
Not very interconnected	**44**	46	43	55	41	43	44	49	42	40	44	49
Not interconnected at all	**13**	13	14	11	9	16	15	21	12	11	14	9
TOTAL NOT INTERCONNECTED	**58**	**59**	**57**	**66**	**49**	**59**	**59**	**70**	**53**	**51**	**58**	**58**
Don’t know	**13**	13	13	3	16	14	15	10	21	11	13	10

Appendix 2 – Furrer+Frey Overview

Furrer+Frey is an engineering company like no other. We are a dynamic team of engineers, consultants and project managers, backed by almost *100* years of Swiss railway engineering excellence.



We began in 1923. Emil Furrer and Arnold Frey founded the company Furrer+Frey. They had learned the overhead line business as engineers and recognised early the potential of overhead contact lines and electrification of the railways.

We have accumulated our experience from developing, constructing and maintaining overhead contact line systems since 1923. Passing it on from one generation of engineers to the next, building our knowledge and understanding through the capital of our company, the engineers and staff working at Furrer+Frey.

We are an SME (Small/Medium Enterprise) this means we are agile and quick to react. We have also worked around the world on a multitude of interesting and challenging projects, from mega projects in China and India to complex projects in over 30 other countries. In the UK alone in the past 2 years we have won awards from the IET for our work on Simulations of electrification performance, Most Collaborative SME at the ICW Awards, Electrification Project of the Year at the UKRIA Awards and trophies at the RailStaff Awards.

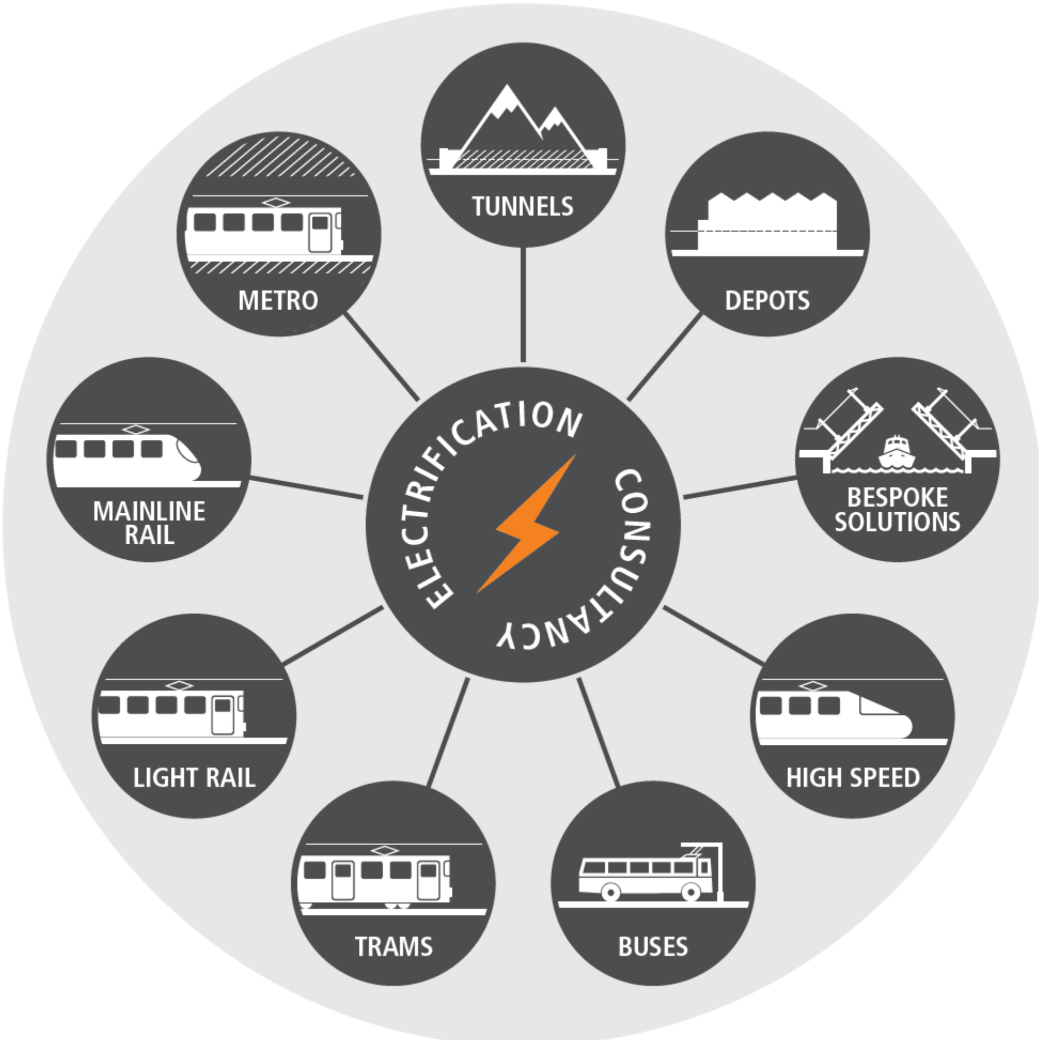
Furrer+Frey also have a tradition of academic excellence, working with Universities around the world. Currently in the UK we are working on projects with Oxford, Birmingham, Sheffield and Cambridge Universities. Our latest joint venture is an Electrification PhD with the University of Sheffield.

Furrer+Frey specialise in the design and development of Overhead Line Electrification systems in all forms of public transport. Our team is first and foremost an engineering design house, but with allied professions such as project management, materials supply and development, logistics and training.

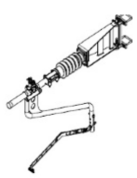
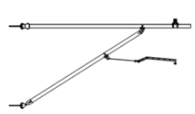
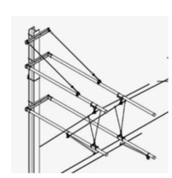
Furrer+Frey's drive for innovation and system development covers various engineering activities in overhead line including: dynamic simulations, design of components and overarching systems, mechanical, electrical, testing, as well as the development of bespoke design software and apps.

Now as the company approaches it centenary it remains a family owned company, currently managed by a 4th generation. Our history shapes who we are today, we retain a family feel, we still have a commitment to pioneering in our field and we are still committed to investing in the intellectual capital of the company.

Furrer+Frey Systems



Furrer+Frey are in a unique situation of having worked for over 90 years solely in electrification. We have developed electrification systems to cover every single aspect of public transport. The table below shows the main key systems used developed by Furrer+Frey.

System	F+F Mainline	ROCS (Rigid Overhead Catenary System)	F+F Rapid Charge	F+F Light Rail	F+F Tramway
Specification					
Design First in use	1980	1984	2009	1985	1990
Route Speed mph (km/h)	Range up to 225kmph	300kmph	70kmph	177kmph	70kmph
Current KM Installed	1600km	5000km	13 routes	300km	400km
Capital Costs	High	High	Low	Medium	Low
Main Use	Mainline Railways	Tunnels, Depots, Bridges	Bus/Tram Routes, Rail Branch Lines	Urban Railway Networks	Rail Branch Lines, Train/Tram Routes, Tram Routes

Notes and References

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[i] United Nations, Nikhil Seth, Former Director of Division for Sustainable development
[ii] Report of the World Commission on Environment and Development: Our Common Future, page 41
[iii] IARC PRESS RELEASE, N° 213, 12 June 2012
[iv] Source Network Rail Wales Route Summary Route Plan Ref SBPT217 Version 1 updated and added to as required
[v] Source: Statistical Bulletin SB114/2015
[vi] Statistics Last Updated January 2016: Welsh Transport Centre
[vii] Statistical Bulletin SB 120/2013
[viii] http://www.lonelyplanet.com/wales/transport/getting-around/train
[ix] As described in Solar Farms in Wales, published by the Welsh Government Research Service in response to enquiry no: 15/0520
[x] Furrer+Frey Survey carried out in conjunction with YouGov between 10th and 13th January 2017, with 1,103 Welsh respondents
[xi] Derived from Britain's Transport Infrastructure Rail Electrification Department for Transport 2009
[xii] Derived from Britain's Transport Infrastructure Rail Electrification Department for Transport 2009
[xiii] Research on dynamic wireless charging of electric vehicles and development of experimental model' was carried out within grant program by European Regional Development Fund for general industrial research and for projects dealing with new product and technology developments. Latvian Investment and development agency Contract number: L-KC-11-0002 project number: KC/2.1.2.1.1/10/01/008.
[xiv] Report – Ove Arup – S. Harrison, G. Henderson, E. Humphreys, A. Smith -
[xv] http://www.ewea.org/wind-energy-basics/faq/
[xvi] www.solar-trade.org.uk/solar-farms/

Furrer+Frey®
Overhead contact lines

Furrer+Frey are a public transport electrification company, who have worked solely in electrification since 1923. Furrer+Frey began working on projects in Wales in 2011 and opened its Welsh office in 2016. Furrer+Frey opened its Welsh office in order to recruit local engineering and manufacturing knowledge and experience.

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