# TUNNEL AGENDA

## CONTENTS

# 1 INTRODUCTION AND EXECUTIVE SUMMARY

Metrotidal Tunnel and Thames Reach Airport are independent private sector initiatives, the first a solution to providing a new Lower Thames Tunnel, the second a new hub airport in the Thames Estuary. While the initiatives are independent they can be fully co-ordinated, with the tunnel providing surface access for a hub airport developed in phases.

Metrotidal Tunnel integrates a multi-modal Lower Thames Tunnel with new flood defences for London, tidal power and data storage. The integrated tunnel infrastructure provides economic growth without an associated increase in carbon audit. This green-growth is achieved through improved transport connectivity, with emphasis on rail, integrated with a flood defence system and tidal power plant that generates and stores renewable energy for supply on demand. The tidal plant includes energy-efficient data storage and distribution. These green-growth agglomeration benefits extend beyond the Thames Estuary region across London and the Greater Southeast.

Thames Reach Airport is the phased construction of a new, 24-hour, hub airport on the Isle of Grain purpose-designed to be time and energy efficient, providing the shortest times for transfer and transit and the lowest carbon audit per passenger; air-side, land-side and for the surface access. This enables the new airport to command the greatest pool of passenger demand and offer the widest range of destinations of any hub in Europe.

The separate tunnel and airport agendas enable policy makers, planners, promoters, investors, stakeholders and regulators to distinguish their separate benefits, impacts and costs. Metrotidal Tunnel provides substantial green-growth agglomeration benefits for the Thames Estuary Region and is viable without an airport while also providing sufficient capacity for the airport surface access. Thames Reach Airport makes use of Metrotidal Tunnel, thereby significantly reducing the start-up costs for the new hub and associated facilities. The low start-up costs and environmental impacts of the separate tunnel and airport developments enable them to be funded by the private sector.

The Thames, the tunnel and the airport create a caduceus of connections between the East and West, heralding a new wave of trade, inward investment and green-growth for Britain in the 21st century.

## 2 THE TUNNEL AGENDA

### 2.1 Agglomeration Benefits

Transport infrastructure can combine separate urban areas to form an agglomerated region with an economy larger than the sum of the parts. The transport has created an agglomeration benefit if the larger economy exceeds the sum of the separate economies along with the cost of the new transport links.

The economic history of London can be seen as a series of agglomeration benefits, first arising from London Bridge agglomerating the ancient trade route of the Thames with a radial Roman road network, accelerated by development of the regions, expanding sea trade, subsequent bridges, docks, warehouses, railways and lately airports, all in turn rapidly increasing the urban economy and drawing in yet more investment. Airports like the docks and warehouses before them are particularly good at generating agglomeration benefits as they increase trade, generate the necessary transport infrastructure and feed the growing conurbation with inward investment. Since WW2 and the shift of the port and trade from the Thames Estuary to Heathrow inward investment has generated substantial growth to the west of London while the closure of the docks to the east has led to the contraction and separation of the Essex and Kent economies north and south of the river. The Thames estuary, for centuries the main artery of trade uniting the north and south banks into a single riparian economy, has now become a barrier between the economies of Essex and Kent. As a result there are latent agglomeration benefits to be found in the Thames Estuary region simply by re-uniting the economies north and south of the river through improved transport infrastructure. A relatively modest investment in new connections provides a large agglomeration benefit across the Thames Estuary region. Consequently a modest investment in new road and rail connectivity is a priority for the Thames Estuary region and is viable and justified by the substantial agglomeration benefits, without considering new aviation capacity.

## 2.2 Integration Benefits

Alongside the agglomeration benefits there are integration benefits from combining a Lower Thames Tunnel with new flood defences for London, a tidal power plant, data storage, utilities and other infrastructure initiatives that are currently being considered in isolation. The combination of these separate initiatives into a single, well-integrated infrastructure project substantially reduces overall costs and impacts while increasing the direct net economic benefits:-

- lower compounded planning and management costs
- lower environmental, habitat and heritage impacts
- lower land acquisition and compensation costs
- the tidal pools provide flood storage for London's new flood defences
- the tidal pools reduce the construction cost of the tunnel
- the tunnel approaches provide access to the tidal pools and power plant
- the tidal power offsets the energy demands of the tunnel and associated infrastructure connections so that the increased transport capacity is accompanied by a reduction in carbon audit
- the resultant constriction of the Thames reduces tidal squeeze upstream

The growth of any large conurbation can be described in terms of optimising the agglomeration and integration benefits to maximise outputs and minimise costs.

## 2.3 Multi-Modal Tunnel vs Road-Only Bridge

A multi-modal (road and rail) tunnel is proposed rather than a road-only bridge for the following reasons:-

- a road-only bridge cannot advance a green-growth agenda
- a multi-modal bridge requires long approaches and heavy structures for freight trains
- a cable-stayed bridge uses more steel so costs more than a ferro-concrete tunnel
- a tunnel is more robust in adverse weather
- a tunnel has a much lower visual impact and less impact on land values
- a tunnel has a lower carbon audit and creates less air pollution

A road and rail corridor approaching on the flood datum (6m) would descend only some 33m to pass under the river through a tunnel while rising some 93m to cross the outer estuary on a bridge. Consequently the fuel consumption of traffic crossing the bridge is higher than that passing through the tunnel. With a 60m lower climb for over 125,000 tonnes of traffic each way per day on the new route, the lower fuel consumption of traffic through the tunnel compensates for the higher embodied energy and maintenance energy costs and results in a lower carbon audit and less air pollution.

An immersed-tube tunnel is proposed rather than bored tunnels for the following reasons:-

- an immersed-tube tunnel can be integrated with the flood defence and tidal power pools to reduce construction costs
- an immersed-tube tunnel has a smaller footprint and cross-sectional area than separate bored tunnels, requiring less land and generating less spoil
- an immersed-tube tunnel is shallower and shorter than the bored tunnel solution
- an immersed tube tunnel is easier to engineer for safety
- the immersed-tube casting basin can be developed as a dry dock

## 2.4 Lower Thames Tunnel

The term Lower Thames Crossing is used to describe a road-only bridge or tunnel located somewhere downstream of the existing Dartford Crossing. Locations upstream of Dartford are by definition not crossing the Lower Thames and serve Central London rather than the Thames Estuary region. The term Lower Thames Tunnel is used to describe a multimodal (rail and road) tunnel downstream of Dartford that relieves congestion at Dartford and provides widespread agglomeration benefits for the Thames Estuary region and beyond.

Various routes for a Lower Thames Tunnel have been considered from beside the existing Dartford Crossing to locations between Southend-on-Sea and the Isle of Grain. Further east than this the costs rise disproportionately compared with the direct net economic and long term agglomeration benefits so these options can be ruled out.

The Metrotidal Tunnel solution to the Lower Thames Tunnel is broadly determined by the following issues:-

- the transport links that result in the minimum cost, minimum carbon audit and highest net economic benefit
- the scope for integrating the tunnel with food defence, tidal power and data storage
- the transport links that result in the largest agglomeration benefits
- the locations where rail and road connections can be united within a single immersed-tube concrete section
- the shortest connections to existing arteries for creating new rail and road networks
- the ability to serve passenger and freight demands
- the site, gradient and curvature constraints of the tunnel approaches

On this basis various locations for Metrotidal Tunnel have been examined including:-

- Thurrock and Swanscombe
- Tilbury and Rosherville
- Tilbury and Denton
- East Tilbury Marshes and Higham Marshes
- Mucking Marshes and Higham Marshes
- Shellhaven and Cliffe Marshes
- West Canvey and St. Mary's Marshes
- East Canvey and Allhallows Marshes
- Hadleigh and Allhallows Marshes
- Southend-on-Sea and Allhallows Marshes

From these options two leading candidates emerge:-

- Tilbury and Rosherville, without integration of flood defence and tidal power
- Hadleigh and Allhallows, with flood defence and tidal power

The Tilbury and Rosherville route provides the minimum cost and minimum impact solution for a Lower Thames Tunnel but without integration. The Hadleigh and Allhallows route provides the most efficient integration of the separate agendas at a single location, resulting in the largest agglomeration benefits and highest net economic output.

Tunnel routes between South Essex and the Hoo Peninsula in Kent have the integration advantage that the broad Sea Reach stretch of the Thames Estuary is wide enough to accommodate substantial flood storage and tidal pools impounded on the Kent side. Further upstream the areas available for impounding a pool beside the shipping channel diminish rapidly and further downstream the tidal range diminishes resulting in lower tidal power output while flood storage capacity has to be much larger in the outer estuary to provide effective flood defences, so the integration of transport infrastructure, flood storage and tidal power is best achieved on Sea Reach.

Tunnel routes further east on the Hoo Peninsula also have the advantage of reducing the rail and road connections required in due course for a Sheppey Tunnel, an immersed-tube tunnel under the Medway between the Isle of Grain and the Isle of Sheppey, thereby extending the agglomeration benefits of the Metrotidal system across East Kent and down to Dover. The latent agglomeration benefits of the Thames Estuary region are sufficient to drive the Metrotidal Tunnel integration on Sea Reach and this easterly location reduces the subsequent cost of the Sheppey Tunnel as part of the complete system.

In summary the Hadleigh and Allhallows Metrotidal Tunnel route is proposed for the following reasons:-

- though a longer distance it is a faster route so journey times are much the same
- provides the best integration of the immersed-tube tunnel, flood defence, tidal power and data storage agendas at a single location
- provides the greatest agglomeration benefits with minimum carbon audit
- reduces the subsequent costs of the Sheppey Tunnel as part of the same system
- minimum impact on existing landscape and habitation

## 2.5 Tunnel Construction

Metrotidal Tunnel consists of a D2T2 or D3T2 immersed tube tunnel i.e. a twin-track and dual carriageway rail and road tunnel formed by casting concrete sections and immersing them in a trench dredged across the river bed. This technique has been used to construct the Øresund link, an immersed-tube tunnel of similar length and section between Sweden and Denmark. Another precedent is the Medway Tunnel, a D2 immersed-tube tunnel that was built in very similar geological and tidal conditions in the Medway Estuary close to the location of Metrotidal Tunnel. With emphasis on rail capacity an initial appraisal suggests that a D2 dual-carriageway road is sufficient. Cost benefit analysis will determine whether the additional cross-sectional size and associated construction costs merit a D3T2 tunnel section for additional long term capacity. The rail and road approaches descend by cut-and-cover construction to reach abutments in the estuary each side of the shipping channel between which the immersed-tube tunnel sections are used. Generally costs are reduced by maximising the cut-and-cover approaches and minimising the length of immersed-tube tunnel. Accordingly the impoundments of the proposed flood defence and tidal power pools on the south side help to reduce the tunnel costs by increasing the cut-and-cover approaches while reducing the length of immersed-tube tunnel across the estuary.

Studies for the existing Thames Barrier at Woolwich indicated that the tidal cross-section of the estuary could be reduced by up to 80% before the reduced tidal range upstream resulted in significant environmental impacts. However throttling the Thames to this degree increases the rate of flow through the constricted channel with the risk of this becoming unacceptable for shipping. Accordingly though the estuary can tolerate a fairly high degree of constriction the size of the pool impoundment on the south side is designed to avoid an unacceptable increase in the tidal flow. The tidal cross-section of the estuary is currently being increased by the dredging of the shipping channel for the new London Gateway container port and by the gradual rise in sea level. The impoundments and tidal pools of the Metrotidal Tunnel system will reduce the tidal cross-section so that on balance the combined effect on tidal range upstream and rates of tidal flow will be small during normal tides.

The casting basin for the immersed tube tunnel sections is formed at Horseshoe Point on the Isle of Grain close to an existing aggregates jetty and depot. The basin excavation here will also be used subsequently for the western approach to the Sheppey Tunnel. The immersed tube tunnel sections are cast in the basin, towed into position and sunk into a prepared trench across the Thames Estuary to be covered over and protected under the shipping lane. There is sufficient width in Sea Reach for shipping to be diverted during the construction process to maintain port operations.

The northern transport corridor approaches over the strip of land between the C2C tracks and the Benfleet Sewage Works, first descending into a cut-and-cover tunnel to pass around South Benfleet at low level between the station and Benfleet Creek. The C2C services are temporarily diverted to the new twin tracks so the existing line and station around South Benfleet can be removed and rebuilt at low level including a four-platform station for interchange between the C2C services and new line. The B1014 having been temporarily diverted during these works is reformed above the new station with a connection to the existing bridge over Benfleet Creek. In this way the existing barrier formed by the C2C tracks and station is removed and replaced by an esplanade and new road overlooking the creek so that South Benfleet is reconnected to the tideway and the transport corridor that had formed a barrier is enclosed within the low-level cut-and-cover construction. The cut-and-cover tunnel follows the curve of the existing tracks and passes the Benfleet Barrier where the new C2C line rises to re-join the existing line over Hadleigh Marsh and the multimodal transport corridor diverges behind Benfleet moorings to follow the line of the existing embankment beside Benfleet Creek. Here the multimodal corridor continues within a protected open-cut for ventilation before re-entering a cut-and-cover tunnel to cross Two Tree Island and descend beneath Leigh Sand, Ray Cut and Chapman Sands to reach the immersed tube tunnel under the Thames shipping channel. Cost benefit analysis will determine whether the immersed tube sections extend as far north as Leigh Sand or the cut-and-cover construction continues to a caisson and abutment for immersed tube sections just before the shipping channel.

The southern transport corridor approaches along the Isle of Grain line past Stoke to descend into a protected open-cut past Middle Stoke and turn north, crossing the old line to Allhallows-on-Sea on the way. The protected open-cut at marsh level continues over Stoke Marshes and Allhallows Marshes to enter a cut-and-cover tunnel just east of the former Allhallows Station site and continue within an enclosed embankment that extends a couple of hundred meters over the mudflats beyond the sea wall before descending to meet the immersed tube tunnel sections under the shipping lane.

## 2.6 Tunnel Connections

The north transport corridor heads west from South Benfleet with the new twin tracks rising to cross the existing C2C line and heading north under the Sadlers Hall Farm interchange to pass North Benfleet and join the existing tracks into Wickford Station. The new highway braches in two providing connections north to the A130/A13 at Sadlers Hall Farm and west to the A13 by Basildon and thence to the M25. As demand increases the junction of the A130 and A129 would be remodelled to provide free-flow.

From the south portal the transport corridor turns to join the Isle of Grain Line heading west. Here the existing single line with minor adjustments follows a fast course and is dualled through to Hoo Junction where a new twin chord is provided south to Higham and existing twin tracks continue as the North Kent Line to Gravesend and Ebbsfleet. New stations are provided at Kingsnorth and Cliffe. The tunnel highway also turns west to follow the Isle of Grain railway before diverging to join the A228 by Hoo St. Werburg. As demand increases the roundabouts on the A228 would be provided with flyovers, the gradient eased on the rise through Chattenden and the junction of the A228/A229 remodelled to provide free-flow.

The second phase of Metrotidal Tunnel provides the Sheppey Tunnel and additional track connections to open regional rail services for passengers and freight. The Sheppey Tunnel is a D2T2 immersed tube tunnel under the Medway connecting the first phase Metrotidal transport corridor on the Isle of Grain with the A249 highway and existing rail services at Queenborough on the Isle of Sheppey. The same casting basin at Horseshoe Point is used to provide the immersed-tube tunnel sections and thereafter forms part of the cut-and-cover tunnel approach from the west. The new transport corridor follows the Isle of Grain Line through the industrial zone where a new station is provided. The second phase also includes the new twin track chord at Hoo Junction from the new Isle of Grain Line to the existing North Kent Line at Lower Higham, and another twin-track chord near Shenfield connecting the Southend Victoria Line with the Great Eastern Mainline.

A third phase adds a twin-track chord from HS1 near Knights Place to the new Isle of Grain Line to open international freight services between Europe and the East Coast ports including the Thamesport, Tilbury, London Gateway (subject to a chord at Stanford-le-hope), and the Haven Ports. These international freight services are extended to the East Coast Main Line (ECML) via 25.7km of new twin tracks between Shenfield and Bishops Stortford via Ongar; the Essex Cross Country Line.

### 2.7 Flood defence

Metrotidal Tunnel includes the integration of new flood defences to protect London from a surge tide. The defences are provided in the form of flood storage capacity, which reduces the level of an incoming surge tide and postpones a permanent barrier across the Thames, which would disturb the estuary ecology and impede shipping. The flood storage capacity is provided by two tidal pools:-

- Pool 1 (10.8 sq.km) beside the Hoo Peninsula upstream of the tunnel with an impoundment on the low-tide line. The existing sea walls within and beside the pool would be inspected and repaired to protect the Cliffe, Cooling, Halstow and St. Mary's Marshes in the event of a surge tide and postpone the managed retreat proposed by the TE2100 report (Thames Estuary 2100 report on flood risks). In the event of a surge tide the pool is flooded via Weir 1 located in the impoundment upstream and opposite the constriction of the estuary formed with Canvey Island.
- Pool 2 (16.2 sq.km) downstream of the tunnel within an impoundment that embraces an area of water at low tide and extends around the Isle of Grain. The existing sea walls within the pool would be inspected and repaired to protect the Allhallows, Stoke and Grain Marshes. In the event of a surge tide the pool is flooded via Weir 2, which is located beside the deeper water within the pool at low tide.

- Pools 1 and 2 are separated by an embankment enclosing the transport corridor that runs in a cut-and-cover tunnel north from Allhallows Marshes to the impoundment by the low-tide line. Weir 3 is formed under the embankment near to Allhallows-on-Sea. After the transport corridor crosses Weir 3 it descends in a cut-and-cover tunnel as it approaches the impoundment to meet the immersed-tube tunnel under the tideway. For much of their length the pool impoundments are generally orthogonal to the swell of the North Sea and can be constructed with relatively light protection compared to similar formations in deeper water exposed to the full force of the open sea. Some additional protection is provided for the 3km prow of Pool 2 where the impoundment crosses deeper water and faces the open estuary.

Existing monitoring systems provide over 24 hours advance-warning of a surge tide. This allows the two pools to be drained at low tide and the weirs closed to retain maximum flood storage capacity ahead of the surge event. The flood storage capacity of the pools depends on the level of the weirs, which include adjustable sluices. The uncertainties of the incoming surge-tide waveform and duration, depending on their interaction with the lunar tide, are managed by recording and analysing the surge as it advances down the North Sea coast. The most effective use of the available flood storage capacity in the two pools is then calculated before the surge arrives in the Thames Estuary.

The configuration of the pools creates a constriction of the estuary south of Canvey Island. While the pools are designed to avoid unacceptable throttling or high flow rates during normal tides the system deliberately provides a throttle in the event of a storm surge. The weirs are kept closed until peak levels and flow rates are reached through the throttle between Pool 1 and Canvey Island. If necessary the movement of ships on the tideway is temporarily suspended during a surge tide so that higher peak flow rates can be tolerated before Weir 1 is opened. An automated system would then open the flood storage capacity in response to the analysis of the incoming surge tide. Weir 3 is left open to unite the capacity of Pools 1 and 2. Their empty, low-tide capacity along with operation of the existing Thames Barrier system upstream is used to absorb the peak surge. The system capacity and operation would be designed to postpone the need for a permanent barrier. The flood storage system's capability is defined by the reduction of the flood risk and the number of years that construction of a permanent barrier across the tideway can be postponed. Simple, economical weir systems are proposed so that the construction and operating costs are well below those of a permanent barrier across the tideway. The effectiveness and duration of the flood defence system depend on the level to which the impoundments and sea walls are raised and the dynamic response to surge tides. The system is designed to protect existing fresh water marsh habitats that would be at risk in the event of a surge under the current TE2100 proposals. If these low-lying areas were included for emergency use the period of protection provided by the flood storage system could be extended.

Set out below are the benefits of a flood-storage defence system over a permanent barrier across the Thames shipping channel:-

- the construction of a permanent barrier is expensive and concentrated in one main phase of work with less flexibility and scope for integration with other infrastructure agendas
- the flood storage pools form part of the integrated Metrotidal agenda helping to reduce overall costs and increase net economic benefits
- the work constructing the pools can be phased starting with Pools 1 and 2, with additional flood storage capacity developed as and when required, thereby spreading the costs over a longer period
- construction over a longer period allows the environmental impacts to be managed over a longer period
- the three weirs and existing barriers serving the flood storage pools are simpler to construct and operate than the gates or floats forming a permanent barrier across the shipping lane
- longer period of protection is provided for existing freshwater marshland and meadow habitats on the Hoo Peninsula than under the TE2100 proposals
- reduction in tidal squeeze upstream of the Hoo Peninsula

- though the pool impoundments look extensive on plan a significant proportion is sheltered from the open sea and follows the natural, shallow, low-tide scour line so they can be a relatively simple earthen embankments with appropriate facings
- the flood storage system avoids impeding the shipping channel, postpones the need for a permanent barrier, and reduces its cost as and when required

The flood storage system reduces the flood risk to very substantial property and infrastructure assets upstream, enabling the ABI to redirect a proportion of the premia raised under the new Flood Re agreement towards investment in the flood storage system. The balance of the construction cost is made up by riparian rates and government grant at a level that would be similar to that required for the TE2100 proposals. At the same time the flood storage pool impoundments reduce the construction cost of the tunnel and tidal power plant, consequently increasing the net economic benefits of the integrated system. The resultant net economic benefits are much higher than for the projected TE2100 investment programme that addresses only the flood risks.

### 2.8 Tidal power

The development of the water-mill is believed to have emerged from Byzantium in the 3rd century BC and recent archaeological evidence suggests the earliest adaptation to a tide-mill may have been on the River Fleet in London towards the end of the 1st century AD. By the mediaeval period there were many tide mills in sheltered creeks and estuaries that could be safely impounded to create a mill race. A few of these tide-mills have survived into the modern era, with notable examples at Carew Castle Pembrokeshire, Eling in Hampshire, Woodbridge in Suffolk, Thorrington in Essex and Three Mills in Bow, the latter being the largest surviving historic group in the world. Of these the simplest and most picturesque is at Thorrington in Essex built in 1831 with a tide pool of just one hectare impounded at the head of Alresford Creek providing a tidal range of six feet. For Londoners a familiar application of the tides would have been the waterworks of Old London Bridge, a profitable enterprise that provided households in the City with pumped water. The original works used a couple of arches at the north end of the bridge and were built by Peter Morris in 1581/82 under a 500 year lease from the City of London. They were destroyed by the Great Fire but replaced by his grandson and later sold to be run as a private company, with additional arches leased at both the north and south ends of the bridge. These mechanical works were one of the sights of London Bridge and continued to operate until 1822 when finally dismantled in preparation for building the new bridge. The narrow arches and broad starlings of the old bridge generated strong tidal currents and a head of up to six feet that drove the waterwheels. In the mid 18th century the works with four waterwheels were pumping over 120,000 gallons of water a day to a head of 120 feet.

So there is a well-established tradition of tidal power from the sheltered estuaries of the East Coast including the Thames. Where viable tidal power was generated through the 16$^{th}$ to 19$^{th}$ centuries with a modest head of water and small pool using oak, apple-wood and cast-iron technology there is now an opportunity to achieve much greater efficiencies and higher outputs from a larger pool with modern marine turbines. The Metrotidal system starts with the simple ebb and flow generation of power from Pools 1 and 2. This two-way operation, with 2,600 times the pool area and over twice the tidal range provides the tidal power output of 26,000 Thorringtons, before taking account of the improvements in 21stC turbine technology and the benefits of tidal pumped-storage operation that are proposed in the later phases of the Metrotidal system.

In a twin-pool, tidal pumped-storage system an external source of energy can be stored in the pools by pumping the levels higher during high tide in one pool and lower during low tide in a neighbouring pool. The high pool operates on average above while the low pool operates below the natural tidal cycles with the stored energy from the pumping being repaid with interest over the tidal cycle. The twin-pool system can provide either a higher output than a single pool or a more uniform output delivered on demand. Intermittent local wind power from the London Array can be used for pumped-storage resulting in a higher value for the wind energy when sold during peak demand. A further advantage of the twin-pool pumped-storage system is that sluicing to and from the sea is not required as all the movement of water is through the turbines of the power plant, either generating power or being pumped. For the Metrotidal system the High Pool is Pool 1 extended to the hillside on the Hoo Peninsula while the Low Pool is Pool 2 enclosing an area of deeper water at low tide. Additional work is required to form the High Pool (16.2 sq.km) from Pool 1 with an impoundment to the Hoo hillside and St. Mary’s Marshes are taken within the pool to become an intertidal area as anticipated under the TE2100 proposals. Some dredging may be required within the deeper water area of Pool 2 (16.2 sq.km) to balance the High and Low Pool outputs. The external energy source can be from a wind farm such as the London Array in which case the twin-pool tidal pumped-storage system can usefully convert intermittent wind power into uniform power on demand (for further information see “Enhancing Electrical Supply by Pumped Storage in Tidal Lagoons” by David J.C Mackay 13 March 2007 and “An Overview of tidal power potential and prospects by F. Lempérière, Hydro Coop, France). For the Metrotidal system the impoundment of Pool 1, when extended to the Hoo hillside, can store water up to 8m datum doubling the estimated power output per square meter from a simple ebb-and-flow system and narrowing the difference between Spring and Neap tide outputs.

The pool impoundments are the main cost of a twin-pool tidal pumped-storage system but with these already provided by the flood storage system the residual cost of the tidal power plant, turbines and associated grid connections is readily justified by the power generated and stored by the system. Sedimentation is managed through alternating the use of the three weirs when filling and emptying of the pools through the normal tidal cycles.

In summary the twin-pool, pumped-storage system provides the following benefits:-

- higher tidal energy output than a single pool
- higher average operating heads for the turbines
- the option of more uniform output
- the ability to serve peak demands
- the storage of tidal and London Array wind energy for sale on demand

- the opportunity to develop tidal pumped-storage technology for subsequent use in very large-scale schemes elsewhere such as the Severn Estuary and the Wash

These benefits provide green-growth for the Thames Estuary region by using the carbon-free tidal and wind energy, stored and distributed by the pools, to offset the energy demands of the new rail orbital, hence “Metrotidal” Tunnel.

### 2.9 Data storage and Utilities

The tidal power system generates electricity from large volumes of seawater passing through turbines between the pool and the sea. Since the tide cycles are predictable the power generated is predictable and subject to the turbines reliable. Data centres require reliable, renewable energy supplies. Modern Tier 4 systems seek secure alternative energy supplies and aim to achieve the lowest PUE (power usage effectiveness) this being the total energy used by the data storage facility divided by energy used by the IT systems. Data storage centres also require substantial cooling loads to maintain a steady-state environment for the IT equipment. The seawater of the Thames Estuary maintains uniform temperatures throughout the year, suitable for maintaining a steady-state environment for the IT equipment and since the tidal pumped-storage system moves large volumes of sea water this can be applied to serve the cooling loads of the data centre, thereby achieving an exceptionally low PUE. The transport connections directly integrated with the tunnel and tidal power plant provide suitable routes for connecting the data distribution and storage centre to existing data networks.

Several existing utilities have key network connections that pass under the estuary not far from the line of the proposed tunnel. The immersed-tube tunnel cross-section includes passages for utilities with the benefit of access for maintenance and renewal. The transport corridors north and south of the tunnel provide routes for extending and connecting existing utility networks across the Thames Estuary region. The sale or rental of utility way leaves (broadband, communications, electricity, gas, mains water, aviation fuel and other private-sector services) contribute to tunnel revenues.

The Hoo Peninsula in Kent is one of the driest areas of the country and has a distant fresh water supply, pumped from the Medway valley. Metrotidal Tunnel forms part of a new water supply grid connecting South Essex and North Kent to provide a more resilient service with lower energy consumption.

## 2.10 Ancillary Development

The new transport infrastructure improves access to sites across the Thames Estuary region stimulating a new pattern of development. This includes ancillary development of sites directly involved in the tunnel construction, where the access improvements are greatest and the works will directly contribute to the site development. The stimulus spreads to neighbouring sites with commercial, industrial and residential development potential.

Set out below are some ancillary and neighbouring developments associated with the tunnel construction:-

### Horseshoe Point dry-dock and deep-water wharf on the Isle of Grain

The casting basin at Horseshoe Point on the Isle of Grain, used for both the Thames and Medway immersed-tube tunnels of the Metrotidal System is located on the western approach to the Sheppey Tunnel where part of the basin excavation can be used for the cut-and-cover tunnel connection. The remaining area of the casting basin can be subsequently developed as a dry dock, representing a subsidy in excess of £200m for this new dry dock facility where none are currently available on the Thames and Medway Estuaries.

### Isle of Grain Industrial Zone

The existing industrial areas and port on the Isle of Grain will benefit from the new accessibility and connectivity of the Thames and Medway Tunnels and the new Grain Station.

### Kingsnorth Industrial Zone

The existing industrial area beside Kingsnorth Power Station will benefit from the new accessibility and connectivity of the Thames and Medway Tunnels and the new Kingsnorth Station.

**Commercial and Industrial Sites:** Other existing commercial and industrial developments sites will benefit from proximity to the tunnels, for example at London Gateway Port, Coryton, Southwest Canvey, Chatham Docks, Hoo Junction, Sheerness, Queenborough and Sittingbourne.

## 2.11 Passengers and Freight

Metrotidal Tunnel provides a new high-capacity bypass to the east of London and new regional routes that relieve congestion at the Dartford Crossing and generate agglomeration benefits across the Thames Estuary region and the Greater Southeast. Metrotidal Tunnel also encourages a mode shift from road to rail use. The locally generated wind and tidal energy from the pumped-storage system will have greater price stability than spot oil, coal or gas. Over time this encourages the mode shift as the lower, more stable energy prices favour rail. The balance of rail and road demand for Metrotidal Tunnel is managed through tariffs and tolls to optimise operations and provide additional capacity without an increase in carbon audit, resulting in a green-growth transportation system. Agglomeration benefits are achieved from the following generic new services and connections:-

Rail

- commuter inner-orbital services for the Thames Estuary Region and East London
- commuter outer-orbital services between Essex, Kent, Surrey and West Sussex
- GC-gauge freight connections between Europe and the Thames Estuary ports
- GC-gauge freight bypass east of London between Europe, the Haven Ports and the East Coast Main Line

Road

- inner-orbital serving the East London Boroughs and Riparian Unitary Authorities
- outer-orbital serving Essex, Kent and the Greater Southeast
- East London bypass for routes between Dover and East Anglia

A wide range of new passenger and freight, rail and road services can be provided through the tunnel on these generic routes, integrating existing infrastructure and connecting systems that are already being developed north and south of the river, such as Crossrail and the SERT and FASTRACK bus networks. The inner and outer orbital rail and road routes are created from relatively short new connections to the tunnel. With the support of appropriate strategic planning policy and the provision of stable, carbon-free energy prices the range of new rail services and the programmes for their development can be led by the market, for example:-

**Crossrail Plus**: The eastern limbs of Crossrail to Shenfield in Essex and Gravesend in Kent are linked through Metrotidal Tunnel to create a “Crossrail Plus” orbital system serving the Thames Estuary region. 25km of new twin-tracks linking the Southend-Victoria Line to the isle of Grain Line creates a 125km Crossrail-Plus orbital around the Thames Estuary. Crossrail has 24 trains per hour (tph) on the Central London tunnel splitting at Whitechapel into 12tph on the eastern limbs north and south of the Thames with the trains terminating and returning at Shenfield in Essex and in due course Gravesend in Kent. As with existing commuter rail services the trains run mostly empty in one direction during the morning and afternoon peaks. This spare counter-cyclical commuting capacity can be used to provide substantial agglomeration and connectivity benefits across the Thames Estuary region. This requires relatively modest investment for the 25kvolt upgrade of the North Kent Line and some capacity improvements at Dartford and Gravesend together with new rolling stock for the additional extent of Crossrail services between Shenfield and Abbeywood. The line connects a large population spread over separate settlements and passes a large area of industrial and commercial development land within the Thames Estuary region.

**Rail freight services**: Metrotidal Tunnel opens new long distance rail freight networks. In the first phase the North Kent Line provides a classic rail freight connection via Hither Green to the Channel Tunnel.

In the second phase the twin-track chord at Shenfield extends these classic continental freight services to the Great Eastern Main Line and the Haven Ports. The second phase also includes the new twin-track chord between the North Kent Line and Isle of Grain Line at Hoo Junction opening an alternative classic freight route via Strood and the Medway Valley Line, subject to a new chord at Paddock Wood heading east. The Sheppey Tunnel in the second phase also opens a classic freight route between Dover and the Great Eastern Main Line, with access from the Channel Tunnel via the Dollands Moor Marshalling Yard, though there are gauge restrictions.

In the third phase a direct connection from HS1 by Knights Place near Cobham in Kent to the Isle of Grain Line is provided bringing European GC-gauge north of the Thames for connections to the London Gateway Port, the Haven Ports and the Midlands. The Treaty of Canterbury reserves 35No. freight trains paths per day each way on HS1 through the Channel Tunnel of which few are used at present. Use of the spare freight capacity is inhibited by the high-speed Eurostar and Javelin traffic on HS1 between Ebbsfleet and St. Pancras International. Both the new Metrotidal Tunnel freight routes, via Dover/Sheppey and via the new HS1 GC-gauge connection at Knights Place, provide new freight connections between the Channel Tunnel, Dover and East Anglia that avoid the emerging passenger congestion on the Thames Estuary and inner London sections of HS1.

The Essex Cross Country Line described below also provides a new freight connection in the third phase between the Channel Tunnel and the East Coast Main Line avoiding inner London congestion or the longer route via Ipswich. The new connections can operate 24/7 and accommodate the longest, 775m trains permitted on HS1.

**Medway Valley Line:** The development of a Sheppey Tunnel in the second phase of the Metrotidal system enables the Medway Valley Line to be extended, in the east from Strood to Queenborough on the Isle of Sheppey (2km new chord at Higham and 9km new twin tracks from Lower Stoke to Queenborough) and in the west from Tonbridge to Redhill and/or Gatwick Airport in due course (with the option of a 3km new chord between South Nutfield and Salfords via Earlswood in Surrey). This line generates agglomeration benefits for the southeast quadrant around London including regional rail access for Gatwick Airport without passing through congested lines in Central London.

**Essex Cross Country Line**: For the third phase of the Metrotidal system new twin tracks (25.7km) between Shenfield and Bishop's Stortford via Ongar complete an Essex Cross Country Line between HS1 and the East Coast Main Line via Cambridge, Ely and Peterborough. An alternative connection between the Essex Cross Country Line and the ECML can be provided via Harlow, Roydon and Ware to Stapleford. This route though some 8km shorter than the Cambridge/Ely/March/Peterborough route requires 9.5km of additional new twin track to form three chords (Housham Tye to Harlow, Roydon to Stanstead St Margarets and Ware to Stapleford). The alternative routes each provide key new freight connectivity between the continent and the UK while relieving congestion on the North London Line through Central London. The Shenfield/Cambridge/Ely/Peterborough route has a local catchment in excess of 3m population with the potential for passenger services between the HS1, ECML and Stansted Airport. With the Central Line extended to Ongar the Essex Cross Country Line provides connections to the Midlands Cross Country Line, East Anglian Line, Stansted Airport, TfL Central Line, Great Eastern Main Line, Crossrail Plus orbital, C2C network, North Kent Line, HS1/Ebbsfleet International/Ashford International and the extended Medway Valley Line, generating agglomeration benefits for the northeast quadrant around London including regional rail access for Stansted Airport without passing through congested lines in Central London.

**Bus services**: Metrotidal Tunnel enables existing bus networks north and south of the Thames such as SERT and FASTRACK to be integrated.

**Road freight services**: Metrotidal Tunnel provides a new road-freight route between the Channel Ports and the eastern seaboard ports north and south of the Thames without making use of the congested M25/Dartford Crossing. The tunnel serves growth areas north and south of the Thames. The road link north via the A130 and A131 to the A120 at Braintree completes a freight network for Essex and East Anglia with the A120 providing the east-west route between Harwich and the M11/Stansted, bisected by the north-south route via the A131/A130 and Metrotidal Tunnel through to the M2 and M20. The Sheppey Tunnel links the A228 on the Isle of Grain with the A249 on the Isle of Sheppey bringing together a group of major commercial development sites in North Kent and South Essex. The Sheppey Tunnel also provides a shorter HGV route between Dover, Essex and East Anglia.

**Chunnel and Portcentric services**: Metrotidal Tunnel enables freight to be directed from existing shipping and highway routes to the rail network. Greater use can be made of freight capacity through the Channel Tunnel, with direct connections between the East Coast Ports (Felixstowe, Harwich International, Bathside Bay, London Gateway, Tilbury, Thamesport, Sheerness) and the industrial heart of Europe. There is considerable scope for reducing road freight and eliminating unnecessary mode changes by directing freight through Metrotidal SRS Tunnel between the English ports, major distribution centres in the Thames Estuary and the European freight network. London Gateway can also be connected in due course.

These are just indicative of the range of new rail services that can be developed to generate the green-growth agglomeration benefits of Metrotidal Tunnel. The market, led by the private sector, will determine the range, capacity and development programme for new rail and road services passing through the tunnels.

## 2.12 Leigh-on-Sea Option

The Southend conurbation extending east from the A130 to the coast suffers from notorious congestion on the A13 and A127. With an additional 1.5km the northern approach to Metrotidal Tunnel can follow the C2C Line from South Benfleet towards Leigh-on-Sea and then turn south under Leigh Creek and Ray Cut to rejoin the route under the estuary. The low-level enclosed D2T4 route around South Benfleet can be extended and enclosed across Hadleigh Marsh to provide flood protection and restore open landscape from Hadleigh Castle down to the creek. A stretch of open-cut may be provided towards South Benfleet for ventilation. The new route would descend beneath the Leigh-on-Sea Station car park where a Southend Park-and-Ride scheme can be provided with connections directly to and from the new highway. Though longer this route also avoids the Two Tree Island Nature Reserve and avocet breeding pools managed by the Essex Wildlife Trust.

For an additional 700m of twin-track cut-and-cover tunnel and 300m of open cutting the Metrotidal route under Leigh Creek can be connected west to the existing C2C line entering Chalkwell Station. With this new connection and a new low-level station beneath the existing Leigh-on-Sea Station car park the existing station and C2C tracks through Leigh to Chalkwell can be removed and the land redeveloped, so that Leigh is restored to being On Sea. A new road, Leigh Esplanade, with valuable residential development is then extended from the new Leigh Station/Southend Park-and-Ride to Chalkwell Esplanade (2.2km incorporating the existing New Road through Leigh-on-Sea) for park-and-ride buses and emergency vehicles only, providing improved visitor connections between Hadleigh Castle, Leigh-on-Sea and the Western Esplanade to Southend Pier. With visitors directed to this new Southend Park-and-Ride/Esplanade the congestion on the A13 and A127 is relieved.

## SUMMARY OF THE AGGLOMERATION AND INTEGRATION BENEFITS

### 4.1 Metrotidal Tunnel Benefits

- high agglomeration and connectivity benefits across the Greater Southeast
- the integration of flood defence, tidal power and data storage agendas to reduce their cost and increase the net economic benefits
- green-growth, i.e. economic growth with a lower carbon audit
- new flood defences in the event of a surge tide
- the generation of tidal power
- the storage and distribution of renewable energy
- energy-efficient, data storage and distribution
- new utility connections across the estuary including fresh water supplies
- ancillary development in Essex and Kent
- relief of congestion at the Dartford Crossing
- the resilience of alternative connections across the Thames Estuary
- the Sheppey Tunnel in a second phase
- new inner-orbital rail and road networks serving the Thames Estuary region
- new outer-orbital rail networks for the northeast and southeast quadrants of London
- new rail services for Stansted and Gatwick Airports
- European GC-gauge freight connections for Essex, East Anglia and the Midlands

M. Willingale July 2013

on behalf of Metrotidal Ltd.