Potential transport energy demand and oil dependency mitigation measures

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Abstract

Transportation, including the movement of both people and freight, accounts for over 60% of all oil consumed globally, while the world’s transportation systems are over 90% dependent on oil and oil by-products. The predicted depletion of oil and subsequent rising fuel prices pose a significant threat to transportation systems worldwide. The choice of transportation system technologies and the use of transportation systems will influence a country’s vulnerability to ‘oil shocks’. Transport and energy planning policies must prepare for the likelihood of such shocks and ameliorate them via policy options. A precautionary approach needs to be adopted to reduce the dependency on oil, in order to improve the sustainability of transportation systems.

This paper addresses the need for oil independence and describes potential ways in which Europe can progress towards this goal. Various mitigation measures for various transport modes are discussed. These measures are ultimately combined into strategies to bridge the gap between oil supply and demand. The objective of the paper is to alert the reader to energy demand management measures available, to the potential impacts of these measures and to the definite need for a move towards new transportation technologies if oil depletion is to be successfully traversed.

Keywords: peak oil, oil dependence, transport energy, energy mitigation.

1 Introduction

Transportation, the platform for economic activity and personal mobility, is entirely dependent on the energy supply that powers it. The transport sector has been the fastest growing consumer of energy in the European Union (EU), accounting for a share of nearly 31% of total final energy demand in 2004 [1]
and 71% of all oil consumption in the EU [2]. The sustainability of the transport sector depends on both the quantity of energy consumed and the sources of energy used. Currently, European transport is powered by petrol, diesel, liquefied petroleum gas (LPG), electricity and jet fuel. Apart from electricity (that is not generated from oil-based resources), all of these energy sources are dependent on crude oil. In fact, 95% of European transport is dependent on oil and, therefore, exposed to oil supply risks. This is highly unsustainable.

This paper addresses the EU’s need for oil independence (section 2) and potential mitigation measures and strategies (sections 3 and 4) to facilitate the achievement of reducing oil dependence.

### 2 The need for oil independence

Oil is a finite, non-renewable energy source. Although it has been abundant and cheap for the past century, at some stage oil production will start to taper off. Current oil fields are rapidly depleting, but there is little consensus about the rate of decline. The International Energy Agency (IEA) predicts the rate of decline to be 6.7% [3], whilst Colin Campbell, the chairman of the Association for the study of Peak Oil and Gas, expects it to be around 2.6% per annum [4].

Another item under dispute is the timing of the production peak. Geopolitical events (such as wars in oil producing countries), extreme weather conditions (like hurricanes in the Gulf of Mexico) and economic factors (e.g. an international recession) could all influence either supply or demand for oil [4].

The IEA does not expect peaking before 2030 [5], while Schoppers and Murphy are 97.5% certain that the peak will occur by 2015 (± 1.26 years) [6]. Many others believe that the peak might have occurred already. To reflect this uncertainty, three oil supply depletion possibilities are considered: firstly that nothing will change before 2030, secondly that a peak is reached in 2020 and, pessimistically third, that peaking occurs in 2012. Figure 1 showcases the resulting transport energy supply trajectories.

Global demand for oil has been growing for decades, resulting from both population expansion and economic growth. In 2007, the IEA forecasted that global oil demand will grow from 85 million barrels of oil per day to 130 million barrels of oil per day by 2030 [7], corresponding to a growth rate of around 2.15% per annum. In 2008, the IEA made a significant downward revision to the 2007 forecast, lowering the expected growth rate to 1% per annum [5]. This revision reflects the impact of higher prices and slightly slower GDP growth, as well as new policies to promote more fuel-efficient vehicles and encourage biofuels. Both an optimistic and conservative growth trajectory is reflected in figure 1.

If oil does peak in 2012, transport energy demand will exceed supply somewhere between 2018 and 2022 (see fig. 1). This leaves a preparatory window of opportunity of 9 to 13 years. Should the peak happen in 2020, problems will start somewhere between 2023 and 2029, leaving a 14 to 20 year period to prepare for it. Even if peaking does not occur before 2030, demand still outstrips supply (from 2029), if demand grows at the optimistic rate.
It is highly unlikely that demand continues along the slow growth trend for the entire period, because demand is linked to economic growth and economic growth is the main aim of most countries around the world. It can be concluded that, if oil remains the world’s primary transport energy resource, transportation systems will face serious obstacles from anywhere between 2018 and 2029. The maximum lead time to try and avoid this is thus 20 years.

3 Measures to mitigate oil and energy dependency

There are various ways and means of either reducing transport’s oil or total energy demand. The most important measures are those that reduce the demand for transport, thereby reducing both energy and oil demand. These measures aim to eliminate excessive travel, although this can only be done to a certain level – some travel will always be required. For the remaining travel demand, the highest priority measures are those that improve energy efficiency. Energy efficiency measures also reduce total energy demand, regardless of the energy source used or the effective modal split. These measures can assist the EU in achieving the target of increasing energy efficiency by 20% by 2020, set by the European Commission in 2007 [9]. The third type of measure is aimed at reducing the demand for oil-based transport fuels, by substituting conventional fuels with alternative energy sources.

3.1 Transport demand reduction measures

Developments in information and communications technology allows for the possibility of telecommuting, online shopping and distance learning, where the
The use of technology substitutes physical travel. The development of sophisticated logistics chains is also enabled. Although many jobs lean themselves towards telecommuting, a certain amount of travel will always be required to allow face to face meetings and facilitate the shared use of equipment. An estimated reduction of between 1% and 10% in car trips is plausible [10].

**Route optimisation** entails planning trips along a route with the lowest generalised energy cost, by taking congestion penalties and empty running into account. In aviation, the shortest available routes are underused due to a lack of real-time and precise information, as well as the unavailability of certain parts of airspace [9]. The potential reduction in aviation emissions through optimised routing is estimated at 6% to 12% [9]. Emissions are related to fuel consumption; hence, emissions savings indicate relative fuel savings.

Efficient usage of passenger vehicles results in less vehicle-kilometres needed to transport the same amount of passengers [11]. A high occupancy rate in passenger cars and buses has relatively little impact on the overall vehicle weight and, therefore, on energy consumption. Measures to increase occupancy rates include ridesharing, carpooling and high-occupancy vehicle lanes.

Increasing vehicle load factors is a way to reduce the growth in freight transport vehicle-kilometres. The fact that some freight transport companies achieve much higher load factors than others in the same sector, suggests that load factors can be improved in the EU [12]. Methods to improve load factors include abandoning just-in-time manufacturing practices, promoting cabotage, avoiding empty return trips and load consolidation (bundling of products via advanced information systems). Estimates are that bundling could reduce the expected future doubling of vehicle-kilometres by 20% to 30% [12].

**Land-use planning** can have a dramatic influence on the amount of transport required in a settlement. Mixed use developments negate the need for long commuter trips and promote the use of non-motorised transport. Although this measure can potentially have the largest impact, it is difficult to estimate the extent to which it can be applied in the EU region.

### 3.2 Energy efficiency improvement measures

Improving vehicle design increases the distance covered per unit of fuel consumed, by: reducing air and rolling resistance, improving engine technology or using light weight materials. New cars consumed approximately 10% less fuel in 2002 than they did in 1990 [13] and this trend is expected to continue. Airlines are aiming for a 25% fuel efficiency improvement through vehicle design by 2020 [14]. Railways can realise large potential savings from light-weighting (up to 20%) and cutting drag and friction (up to 10%) [15]. Technology options for reducing energy use in the shipping industry include hydrodynamic improvements and machinery; these technologies could reduce energy use by 5% to 30% on new ships and 4% to 20% on retrofitted old ships [16].

**Vehicle maintenance** is very influential in terms of fuel efficiency. According to estimations, fitting appropriate tyres and maintaining proper tyre pressure can improve vehicle fuel efficiency by more than 5% [10]. Keeping engines properly tuned can save 4%, checking and replacing air filters regularly
up to 10% and using the recommended grade of motor oil can save up to 2% [10]. Flight Sciences International [17] indicates that improved maintenance reduces aviation energy consumption between 5% and 10% over the long term.

Another key area to improving energy efficiency is vehicle renewal practice. This affects the average age of the vehicle fleet, as well as the average size and efficiency of vehicles. Old vehicles should only be replaced with newer, more efficient technology vehicles. To illustrate: new aircraft are typically 70% more fuel efficient than 40 year old aircraft and 20% better than 10 year old aircraft [14]. The majority of new heavy vehicle engines are electronically controlled, providing a 7% to 15% improvement in fuel economy [18]. The European Commission (EC) has launched initiatives to promote a market for greener vehicles (i.e. the Car Fuel Efficiency Labelling Directive (1999/94/EC)) [19].

Vehicles with smaller engines are more fuel efficient, especially in urban areas. It is estimated that the move towards smaller vehicles will reduce total fuel consumption by between 10% and 20% [10]. In freight transport, matching engine size to the required task will give the best fuel economy.

Better driver education and public campaigns provide the possibility to reduce fuel consumption substantially. Aggressive driving (rapid acceleration and braking) wastes energy. In road-based transport, improved driving behaviour can reduce fuel consumption by up to 33% [10]. The ECODRIVEN project (2006 to 2008) is an example of such an education programme [9]. In rail transport, fuel usage can vary by 12% to 20% between crews [20].

Intelligent transport systems (ITS) can be utilised to manage traffic in a more efficient manner. This would entail reducing idle time (when fuel efficiency is at its lowest) through optimised signal settings and managing speed (with variable speed limits, for example) to improve traffic flows. Such measures have been demonstrated to save between 5% and 20% of fuel consumption [10]. Air traffic management enhancements could improve fuel efficiency and reduce CO₂ emissions by up to 12% [14].

Information on actual traffic flows can help drivers to avoid routes that are heavily congested, thereby reducing idling time and fuel consumption, accordingly. Modelling studies estimate that, if between 20% and 40% of road users are fully informed, network efficiency improves with up to 10% [10]. Live information on a vehicle’s fuel demand can assist drivers in driving more economically. Fully automated driver assistance systems can save up to 23% [21]. Fleet vehicle tracking systems introduced by freight companies can result in a reduction in fuel consumption by between 15% and 25% [19, 22].

ITS initiatives underway in the EU include: the Intelligent Car Initiative, the SESAR programme, the ERTMS system and the River Information Services (RIS) system [2]. The Commission is currently involved in two global navigation satellite system projects: EGNOS and GALILEO [9].

Inter-modality (the efficient use of different modes on their own and in combination) results in the optimal utilisation of resources, including energy [19]. Inter-modal systems typically make use of the most efficient modes (i.e. rail or water) for long segments of a journey between hubs, combined with road transport for shorter segments (spokes). Trans-European Networks for Transport
(TEN-T) aims to promote the interconnection and interoperability of and access to national networks [9].

All modes of transport are not equally energy efficient. The most efficient modes should enjoy the highest priority in terms of planning and development. In passenger transport, air transport has the lowest energy efficiency, followed by private cars, motorcycles, buses, rail and non-motorised transport (NMT) respectively. For freight the order of increasing efficiency is: air, road, rail, water and pipeline transport. Presently, road transport accounts for the lion share of both passenger and freight transport (see figure 2). Public transport (excluding air) constitutes 16.1% of passenger transport. There appears to be quite some scope for a modal shift towards public transport in the EU. A shift between motorised transport and NMT (cycling or walking), results in a 100% transport energy reduction for the same amount of travel. The utilisation of rail, pipelines and inland waterways in freight transport can also be increased.

![Figure 2: European passenger and freight transport modal shares [1].](image)

**Economic instruments** (taxes, charges or emission trading schemes) can encourage transport users to switch to cleaner vehicles or modes, to use less congested infrastructure or to travel at different times [23]. Price signals are the most effective when the market offers realistic alternatives (e.g. cleaner vehicles at an affordable price or appropriate levels of service in other modes). Fuel prices can influence consumer choice, both in terms of the quantities and the type of fuel purchased. Moreover, persistent price differences can influence decisions on the type of vehicle purchased, leading to changes in the vehicle stock and fuel mix over time [1]. The extent of potential savings needs to be assessed on a case by case basis, as many factors can influence the effectiveness of this measure.

### 3.3 Alternative fuels and propulsion systems

In 2001 the European Commission (EC) set out a strategy to achieve a 20% substitution of conventional automotive fuel by 2020, identifying biofuels,
natural gas and hydrogen as the main replacement possibilities [9]. Subsequently, in 2008, the EC proposed a directive requiring each member state to have at least 10% of its petrol and diesel fuels for transport coming from alternative fuels by 2020 [9].

Biofuels (mainly biodiesel and bioethanol) are slowly, but steadily, increasing its market share in the EU, although it is still limited at present [24]. The main driving force behind the increase is government policies introduced in response to the EU Biofuels Directive (2003/30/EC), which sets the European biofuels market penetration target at 5.75% in 2010 [1, 13]. To increase volumes further, fuel standards need to be adapted, distribution needs improvement and the compatibility of the vehicles with biofuels needs to be improved. The maximum biofuels market penetration percentage is 5% [1, 13] with existing fuel standards.

Though biofuels will lessen the reliance on crude oil, it cannot untie itself completely from oil at present. This places a question mark on the long term sustainability of the biofuels industry. However, in the 2006 review of the Biofuels Directive, respondents proposed market penetration targets of 8% by 2015 and between 15% and 20% by 2020 [25].

Alternative fossil fuels currently commercially available are Liquid Propane Gas (LPG) and Compressed Natural Gas (CNG), but their market shares are limited to specific niches [24]. Because these fuels are dependent on non-renewable resources, they are not considered a viable alternative to oil.

The IEA does not expect any major shift away from conventionally-fuelled vehicles before 2030, although the penetration of hybrid-electric cars is projected to rise, reducing oil demand growth [7]. The fuel efficiency improvement obtained from switching to a hybrid-electric car can be more than 100% [26]. These vehicles are already on the market. It is believed that this is a very viable option to reduce oil dependency, if combined with government incentives. However, the number of hybrid car models available on the European market has changed little between 2001 and 2006 [24]. It should be noted that the concept of hybrid propulsion can also be applied to other transport modes.

Electricity is a budding contender in the alternative fuels industry. Some advantages of using electricity to power the transport sector include: the existence of the core infrastructure, the relatively high efficiency of electric propulsion and the possibility to generate electricity from renewable sources (increasing sustainability and mitigating environmental impacts). Electricity already powers rail lines and some public transport vehicles. Disadvantages are that transport will have to compete with other sectors of the economy for electricity in a system that is currently quite strained, the problem of centralised filling stations needs to be solved, exposure to the risk of power failures and the current state of technology development in terms of vehicle range, cost, availability and the need for expensive battery replacements [26].

Some alternative propulsion systems can be powered by electricity, for example magnetic levitation (maglev) and tubular freight systems. Maglev systems are incredibly energy efficient and have high performance levels. They consume approximately a tenth of the energy required by an average automobile per passenger-kilometre [27]. In low pressure tunnels the average energy
efficiency could potentially be increased to around 4000 km/l [27]. Even though the advantages of maglev seem to outweigh the disadvantages, the main obstacle to the wide-scale adoption of this technology is cost. There are six functioning maglev systems in the world at present and new systems are currently being considered in 12 countries. Many maglev research projects are underway [27].

Tubular freight transportation is a group of unmanned transportation systems in which close-fitting capsules or trains of capsules carry freight through tubes between terminals [10]. Although research and development around tubular freight (and passenger) systems has been emerging for several decades, no final conclusion regarding the feasibility and energy efficiency benefits have been reported.

Hydrogen (fuel cell technology) is a clean alternative fuel that is not necessarily dependent on fossil fuels and causes very low to zero emissions when used in fuel cells (assuming good production and transportation practice). The future of hydrogen within the transport sector is uncertain, as there are still many issues that need to be resolved (such as the storage and transportation of hydrogen, safety concerns, infrastructure requirements, high costs involved, vehicle performance and low energy efficiency) [26]. Hydrogen is an energy carrier, not an energy source. Energy thus needs to be converted to hydrogen from another source and from hydrogen to electricity, incurring energy losses of between 57% and 80% [28]. So much energy is lost in the manufacture, distribution and final use of hydrogen in the fuel cell, that it is less energy efficient than a petrol-electric hybrid car [10]. Creating hydrogen through electrolysis is less efficient than using electricity directly in electric vehicles [10]. Developing the infrastructure required to convert to a hydrogen economy has very long lead times (10–15 years) [26].

Despite all the obstacles facing the wide-scale adoption of hydrogen as a transport fuel, a lot of research is currently being invested in. An example is the Zero Emissions Ships project (ZEMSHIPS), which demonstrated the functioning of the first hydrogen and fuel cell powered ship (with a capacity of more than 100 persons) [9]. In 2007, the EC proposed extending the scope of the EU's type approval system for cars, vans, trucks and buses to include hydrogen as a fuel, to facilitate the introduction of this technology into the EU market [9].

Prototype vehicles incorporating compressed air technology (CAT) have recently been introduced to the market by Moteur Development International [26]. CAT vehicles are claimed to have a driving range close to 2000 km, with zero pollution in cities and considerably reduced pollution outside urban areas. These vehicles are a very recent addition to the alternative propulsion arena and thus little verified information is available on them.

3.4 Summary of energy demand and oil dependency mitigation measures

Based on the literature available, projections were made regarding the potential energy savings that could be achieved by 2030, through the implementation of measures. These projections take the modal split, as well as the split between passenger and freight transport per mode, into account. A modal shift (comprising a 15% road to rail freight shift and roughly a 25% shift from air and
private vehicles to public transport an NMT) proves to be the measure with the highest savings potential (26%). This is followed by the wide-scale adoption of hybrid cars (21%) and biofuels (17%).

Measures are not mutually exclusive and, when they are combined into groups, the interaction between measures must be taken into account. For example: improved traffic signal settings will decrease the potential for savings from improved driver behaviour (which minimises stop and go driving). It is very unlikely that the full potential of any measure will be realised. All elements that could influence the success of a measure cannot be controlled or foreseen.

Alternative fuels can reduce oil demand (but not necessarily energy demand) the most. If 55% of all road vehicles were replaced with alternative fuels (20% E-85 biofuels, 25% hybrids and 10% either electric or hydrogen), an estimated maximum of 34% of oil demand could be eliminated by 2030. A potential pitfall for alternative fuel technologies is described by the Khazzoom-Brookes postulate [29]. It states that, when a person acquires a vehicle that is more efficient, (s)he will simply drive it more, negating the potential benefits. Time constraints counteract this tendency [26]. Combining alternative fuel strategies are ultimately expected to realise an estimated 18% saving by 2030.

Of all the efficiency improvement measures, the modal shift is the best, seconded by the roll-out of intelligent transport systems (13% saving). Combined, a saving of 17% can be expected from the implementation of efficiency improvement measures. Demand reduction measures can, similarly, account for a 15% saving by 2030. Vehicle load factor and passenger occupancy optimisation is the most effective demand reduction measure.

4 Bridging the oil supply and demand gap

Tables 1 and 2 indicate the shortfall (negative) or surplus (positive) oil supply by 2030 (expressed as a percentage of demand) in each of the three supply scenarios and for three mitigation strategies. If demand grows at a conservative rate (as explained in section 1), there is excess supply in the no peak scenario (see table 1). If a peak is expected, however, demand reduction strategies (strategy 1) will suffice to bridge the oil gap, if peaking happens during the latter half of the period. A combination of energy efficiency and demand reduction measures (strategy 2) are sufficient to close the gap in this scenario.

Considering the optimistic demand growth scenario (as explained in section 1), if there is no oil peak before 2030, the supply of oil will not be enough to satisfy the projected demand. None of the three mitigation measure groups can alone traverse the oil gap successfully, regardless of when peaking occurs. The measure groups will, thus, have to be combined. It is prudent to remove unnecessary demand from the system before trying to improve the efficiency of the demand that cannot be removed; therefore, demand reduction measures are applied first (strategy 1). Only if there is no oil peak will this be enough to bridge the gap (see table 2). Combining demand reduction and efficiency improvement measures (strategy 2), results in a supply deficit in the 2012 oil peak scenario only, requiring a combination of all three measure groups (strategy 3).
Reducing the demand for oil has additional benefits to avoiding a devastating supply shortfall. Every barrel of oil saved (dubbed nega-barrels) is worth just as much money as a regular barrel of oil to the EU, either due to reduced production or reduced import costs [15]. A 16% saving in oil imports converts to 696.65 million barrels saved. At a (low) crude oil rate of $35.30 per barrel, this equals a saving of €19.43 billion. Similarly, a 45% saving would be worth €54.64 billion. At a high oil price ($150 a barrel), the 16% saving is worth €80.88 billion. This analysis showcases the value of reducing oil dependency, regardless of the occurrence of an oil peak.

Table 1: Transport energy supply scenarios – conservative demand growth.

<table>
<thead>
<tr>
<th>Oil Supply Scenarios</th>
<th>No Peak</th>
<th>2020 Peak</th>
<th>2012 Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSERVATIVE demand</td>
<td>29%</td>
<td>-6%</td>
<td>-28%</td>
</tr>
<tr>
<td>Demand Reduction (1)</td>
<td>50%</td>
<td>10%</td>
<td>-16%</td>
</tr>
<tr>
<td>(1) + Efficiency improvement (2)</td>
<td>80%</td>
<td>38%</td>
<td>5%</td>
</tr>
<tr>
<td>(1) + (2) + Alternative fuels (3)</td>
<td>157%</td>
<td>89%</td>
<td>44%</td>
</tr>
</tbody>
</table>

Table 2: Transport energy supply scenarios – optimistic demand growth.

<table>
<thead>
<tr>
<th>Oil Supply Scenarios</th>
<th>No Peak</th>
<th>2020 Peak</th>
<th>2012 Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTIMISTIC demand</td>
<td>-1%</td>
<td>-28%</td>
<td>-45%</td>
</tr>
<tr>
<td>Demand Reduction (1)</td>
<td>16%</td>
<td>-15%</td>
<td>-35%</td>
</tr>
<tr>
<td>(1) + Efficiency improvement (2)</td>
<td>45%</td>
<td>6%</td>
<td>-19%</td>
</tr>
<tr>
<td>(1) + (2) + Alternative fuels (3)</td>
<td>99%</td>
<td>46%</td>
<td>11%</td>
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5 Conclusions and recommendations

There is an important distinction between mitigation measures: those that save energy, regardless of the energy source, and those that only reduce oil dependency. Because the measures only focused at oil dependency (mostly alternative fuels and propulsion systems) will stimulate greater demand for other energy sources (such as electricity, natural gas, etc.) and resources (agricultural land for biofuels), it is important to evaluate the sustainability of switching energy sources. It is unwise to solve one problem by creating another; hence it is recommended that measures reducing total energy demand be given preference over measures simply aimed at reducing the demand for oil. Demand reduction and energy efficiency improvement measures are generally less expensive and have shorter lead times than that required for a switch to alternative fuels.

For many viable mitigation options to have substantial impact, they must be initiated more than a decade in advance of peaking. An analysis of the European disposition regarding oil depletion (section 2) shows that the maximum lead time at the EU’s disposal is 20 years. The lead time required to implement mitigation measures (often in excess of 10 years) stresses need for governing bodies to start reducing oil dependency now.

It can be concluded from section 4 that applying measures individually will not suffice to bridge the supply and demand gap that will follow peak oil. Depending on the timing and extent of the peak, different combinations of
measures are required. The most promising mitigation measures are the facilitation of modal shifts, increased market penetration of hybrid vehicles, the implementation of intelligent transport systems and increased average vehicle occupancies (load factors for freight).

It should be kept in mind that demand will eventually overtake supply, albeit not before 2029. Regardless of whether there is an oil peak or not, it is worthwhile to reduce a country’s oil dependency, because every nega-barrel is worth as much as a regular barrel of oil. Likewise, reducing the demand for other forms of energy can also lead to monetary savings.

At the time when this paper is written, the world is moving into an economic recession. This significantly impacts global oil demand, delaying the impending oil peak. In terms of transport readiness, this is somewhat of a blessing in disguise. The opportunity now exists to start planning for the oil peak in a timely fashion, because the lead time for preparation is extended. During recessionary periods, governments tend to increase their infrastructure spending, in order to stimulate the economy. This creates the opportunity to start investing in the infrastructure required to step away from oil. Budgets should not be allocated to projects that will foster the current transport status quo. Reduced global oil demand has resulted in low prices. It is relatively inexpensive to undertake infrastructure projects at present, compared to what it will cost after the oil peak has occurred. The authors would like to highlight the need for governments to start peak oil mitigation now, although it might seem like an unlikely time to do so. Carpe diem.

References

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