Executive summary

Free movement of individuals and of goods is vital for modern society and economy. A freedom of mobility on Earth is provided by legal arrangements and through a transportation system with travel by air, rail, road, water, etc. (at speeds of: 1000, 150, 100 and 50 km/hour respectively). In the 21st century there is a clear demand to travel faster, safer, in more comfort, at less costs, with less congestions, less dependence on weather and in a sustainable way: with less use of fossil fuels, with less emissions and pollutions, less noise, vibrations, carbon footprint, etc. None of the existing transport means satisfy these requirements in full and a search for alternatives continues (e.g., electric cars, airplanes, helicopters, ships).

Evacuated Tube Transport (ETT) Technology (ET3, [1]) allows addressing all the needs mentioned above. It uses capsules to transport people, goods, energy and data, etc. with a speed ranging from 600 to 6000 km/hour. A car-size capsule (with up to 6 people) is positioned inside a 1.5 m diameter tube at a certain distance from the tube walls using magnetic levitation (arranged e.g., with permanent magnets inside the tube walls and high temperature superconductors inside the capsule). It is ac- and decelerated using linear motors and generators placed inside the tube walls around the stations. Energy used to accelerate the capsule, is almost completely recovered during capsule deceleration. A vacuum inside a tube allows eliminating air resistance and magnetic levitation takes care that there are no other kinds of friction (normally associated with vehicles), thus a capsule moves between two stations with (almost) constant speed without need for an engine.

ETT is similar to a transport by road. It uses a network of evacuated tubes to bring people and goods to their destination directly, quickly, safely, cost competitively and in the most sustainable way. Capacity of ETT depends on the capsule speed. For instance, one tube at the capsule speed of 600 km/hour can transport up to 0.24 million persons/hour or 16000 ton/hour of cargo (the tube capacity increases linearly with the capsule speed) [1]. Al l capsules are computer controlled, and therefore no drivers needed. Each capsule travels through the network of evacuated tubes independently and directly to its destination (with no intermediate stops). Computer control and capacity of ETT network ensures that no congestions possible.

Estimates show that in the Netherlands at present 22 B€/year is spent on travelling (by train, plane and car). Assuming that 50% of this amount is spent on travel inside the country, 11 B€/year is available. We further assume that when the network is operational, 6-9 B€/year will be available as a revenue for ETT (considering that ETT has no alternatives regarding speed, costs, comfort of travelling, safety, maintenance, sustainability, etc. [1]).

Installed ETT costs are 3 M€/km (including stations, etc. [1]), therefore an investment of 9 B€ in 3000 km of ETT network can be earned back in 2-3 years of operation*. Thus, a sustainable business (with interest rates of 10 to 30%) is assured with ETT, even when additional revenues from transporting e.g., goods, energy, data through the same ETT network are not considered.

Note that ETT network operated at a capsule speed of 600 km/hour will cut dramatically travel times (to less than 20 minutes anywhere inside the Netherlands. Saving of 0.5 hour/day travel time per person for the Netherlands converts in saving of over 5 B€/year (almost 6 B€/year is currently lost in the form of hours spent on travelling by train, plane and car, see below).

When operated at the maximum capacity, the Dutch ETT network will be capable to serve over 1 billion passengers annually; in other words it will require in total less than 2.5 hour/day to transport all passengers in the Netherlands currently using car, rail and air for travel[**]. And, during remaining 21 hours/day ETT network will be available for transporting goods, energy, information, etc. This transport will create additional revenues, not included in this document.

In the Netherlands due to the flat landscape and relatively short distances, a low-speed ETT network (600-1000 km/h) can be built using elevated ETT design (by 5 m, at estimated 3 M€/km, see [1]). An important for the country aspect is that from the beginning ETT network can be built to remain operational during a flood, (that is built mostly above the sea level) and it can be used as an emergency evacuation system in the event of a flood, providing an important safety measure for parts of the country below the sea level (e.g., Randstad).

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[*]Expected ETT ticket costs are 0.01 €/passenger-km [1] as compared to 0.11 €/passenger-km for train and plane and to 0.15 €/passenger-km for cars, see below. Therefore it is fair to assume that when needed, up to 50% of the expected ETT revenues (6 B€/year) can be used as return payments to investors, in order to make the investment very attractive (interest up to 30%), considering importance for the country and for the population of timely implementation of the ETT network.

References

[1] D. Oster, M. Kumada, Y. Zhang, "Evacuated tube transport technologies (ET3): a maximum value global transportation network for passengers and cargo", Journal of modern transportation, vol. 19, nr. 1, March 2011, pp. 42-50.
[2] NS annual report 2011
[3] KLM annual review, fiscal year 2010/2011
[4] Roy Zuijderduin, Oleg Chevtchenko, Johan Smit, Gert Aanhaanen and Rob Ross, "Strengthening future electricity grid of the Netherlands by integration of HTS transmission cables", paper presented at EUCAS 2013, preprint is available on request.

Facts and figures:

NS [2]: Revenue in year 2011: 3.63 B€ (1.9 B€ from domestic tickets), 16.8 B passenger-km, or 0.11 €/passenger-km. Time spent on travel: 16.8 B passenger-km/(150 km/h) =0.112 B hours; x 10 €/h = 1.12 B€/year.

Total NS, travel by train: 3.63 + 1.1 = 4.7 B€/year.

KLM [3]: Revenue in fiscal year 2010/2011: 8.65 B€, traffic: 77 B passenger-km (or 0.11 €/passenger-km), average speed: 500 km/h (for a 4 hours flight including 4 hours waiting and additional travel time), time spent on travel: 77 B passenger-km/(500 km/h) = 0.154 B hours; x 10 €/h = 1.54 B€/year.

Total KLM: 8.65 + 1.54 = 10.2 B€/year.

Cars: according to World bank (www.data.worldbank.org), Dutch people made with cars 153300 mln passenger-km in a 5 years period (2009-2013), which is on average 31 B passenger-km/year. Assuming 0.15 €/km, the amount is 4.5 B€/year. Time spent to travel at 100 km/h: 31 B passenger-km/(100 km/h)= 0.31 B hours; x 10 €/h = 3.1 B€/year.

Total travel by road: 4.5 +3.1 = 7.6 B€/year.

[**]Notably, because of much higher transportation speed and capacity, an ETT network (at 600 km/h and 0.24 M passengers/hour) will need just 0.6 hours/day for passengers transport to provide the same $3.1*10^{10}$ passenger-km/year as provides travel by car during a year. Considering the totals, ETT within less than 2.5 hours/day can transport all passengers in the country currently travelling by road, rail and air.

Total travel by train, plane and car: 4.7+10.2+7.6 = 22.5 B€/year.

ET3 Netherlands plans realization of ETT network in the Netherlands and internationally in the period from 2014 to 2021 in five phases, see details at: http://et3.nl/funding.html

To accomplish the task of creating an ETT network in the Netherlands, Maglev Institute will require a funding of at least 6.35 B€. As shown above, this investment will be recovered within one year of operation of the ETT network (3000 km).

Phase 1 will start early in year 2014, with a duration of 3-6 years and it requires a funding of € 100 mln.

During this phase: a multidisciplinary academic research will start and required knowledge will be created for implementing ETT and HTS power cables in the Netherlands and abroad, total duration of this activity is 3-6 years; a company HTSpowercables.nl will be set up and operated; implementation of HTS power cables will be prepared and started, and of ETT will be prepared in the Netherland; existing laboratory will be upgraded; a functional ETT model with a 50 m long track will be developed and demonstrated; a 30 m-long HTS AC 380 kV transmission cable will be developed and tested[π]. As a result of this phase, an implementation in the Netherlands of ETT will be prepared and of HTS transmission cables will be started. A provisional breakdown of the costs is listed in Table below.

Table Provisional breakdown of the required costs for Phase 1.

	Phase 1 (years 2014-2016):	M€
1.1	Research and knowledge build-up (years 2014-2019)	30
1.2	HTSpowercables.nl started and operating	10
1.3	Preparations & implementation of HTS power cables in NL	15
1.4	Preparations for implementation ETT in NL	21
1.5	Upgrade existing laboratory (relevant to ETT, HTS cables)	10
1.6	A functional model of ETT demo, 50 m (year 2016)	6
1.7	A 30 m-long HTS power cable 380 kV tested (year 2016)	5
1.8	Other costs, contingencies, etc.	3
-	Total, M€	**100**

[π]Electricity transmission network of the Netherlands is managed by TenneT. The 380 kV part of the network (single circuit) is 2127 km long and for 95% is made of overhead lines (OHL). An OHL serves for 40 years and TenneT has to replace on average 53 km/year of aged OHLs (using some 300 M€/year) in order to keep integrity of the network. Novel HTS transmission underground cable developed at Technical University of Delft [4] allows replacing an OHL cost-competitively and with many other benefits. After completion of the relevant project at TU Delft, the new company HTSpowercables.nl B.V. takes care that with time transmission (and later distribution) networks of the Netherlands will transform from overhead into underground, namely from OHL and conventional copper cables to HTS cables. A 380 kV OHL needs 80-150 m-wide right of way (mostly above ground) and a HTS cable transmitting the same power needs 2 m wide right of way (underground). The land that will become free as a result of activities at HTSpowercable.nl can be used for building ETT network (a 5 m-wide strip is needed). This way a synergy between ETT and HTS power cables will be provided.