Project Msziget-15-99

Entry level plan,

professional documentation

Last modification (base HU version): 24.09.2013

Translated: 24.09.2013

Introduction

Our organization near one decade before discovered a serious problem, which named 26-15-99 by number of route. That mark routes of local transit provider BKV where public traffic is minor, therefore public transport emit most of environmental pollution. Moreover, there depreciate vehicle fleet is additional problem. In Isle Margit route 26 spread 1300kg contamination in a year. Route 15 and 99 many times pass through walking street and between high buildings in a narrow way. There exhaust gas accumulating, in that way provide major part of air pollution. Air pollution is not only problem, because noise pollution is a major problem too. In that way related routes spread 15000kg contamination by the side of its routes.

Using strong language, isle Margit ought to park with clean air and help to relax. This is because unfortunately Budapest has less green area and has heavy environmental pollution (air and noise). Instead, near quarter of Isle is paying car park and buses of public transport assure city-level noise and air pollution periodically. Unfortunately that situation is same for route of 15 and 99 where need have silent streets of city centre with relative clean air. From civilized viewpoint that situation is unsustainable. Have affect to health, scare away visitors, whit this make damage which measurable with cash.

Our organization many times deal with that problem. Now we pay of our debt and we present our complex plan at name Msziget-15-99.

Question come up, if exist any project which make situation better, how to finance it in middle of economic crisis? The answer is, if project well express its target and we use our head, then problem is bridgeable.

Object

Succinctly expressed object of that project is to improve quality of travel for example with restructuring or replacing vehicle or its technology. In addition reduce cost of travel for example with reducing cost of operation and cost of environmental pollution. Additional object of that project, investment must be less than cost of replacement to new vehicles which use old technology.

Changing duration is not object of that project, but as we show later as secondary effect duration can be decrease, and stability of duration can be increase.

Secondary object of that project is make people think about majority of environment protection and point: there is can be other way.

Components

That project has three components which closely linked together:

First component is, environment protection revision of Isle Margit including public transport.

Second component is, solving problem of route 15.

Third component is, revision of route 99.

Routes

15 (original)

The route terminated in a present form. Its function directed to route 15.

Route length - 4,6km

Duration - 25p

26 (original)

The route terminated in a present form. Its function directed to route 15. Reason is, to maintain “green” route on a near same direction is impractical. Newly created route linked together at Szent István boulevard at street Szemere and Honvéd and run to Boráros square.

Route length - 4,5km

Duration - 18p

15

Route 15 extend using route of old 26.

Route length + 4,2km = 8,1km

Duration + 15p = 36p

26A

North part of 26 and 15 linked route used frequently at evening and weekend. Therefore, suitable to turn back every second vehicle at Kossuth square.

Route length 4,8km

Duration 17p

99 (original)

Route 99 split to two part, 99A and 99B.

Route length - 11,6km

Duration - 42p

99A

Become “green” part of a route. Route run from Népszínház to Rade Károly street. Route must extend through Rade Károly and Hazinszky Frigyes walkway to Népliget Metro stop. That is help to make convenient final stop.

Route length 5,2km

Duration 17p

99B

That is “grey” part of a route. At Petz Ármin walkway linked to “green” part of a route.

Because traffic, outer part of a route must be operated. Technology of can be normal diesel (EUR4). Routes must be synchronized at changing point (Petz Ármin walkway).

Route length 6,4km

Duration 25p

Lehel square

Because parallel metro and trolleybus route, north from Szent István boulevard short part of route 15 can be terminated. If it is required nevertheless, then route 133 can be extended there.

Nyugati square

Based on that conception routes keep away from Nyugati square. First reason is, near permanent traffic jam here. If route escape form boulevard soon as possible, then duration can stabilized. Second reason is, it is suitable to shift change form metro line 3 to Árpád bridge at north part of Isle, because south part of Isle overloaded.

Implementation, road expansion

Isle

Road

Pavement of Isle’s North-south road must be replaced 2,1km.

All public lighting must be replaced.

Car park

It is desirable to put all car park (around the hotel) to underground. One possible economic way to do that, cover all car park and from green area on (13.000+1000+1500=15500m2).

Recommended to lead contaminated air of a car park over flue which higher than Árpád bridge and located north from ramp of.

To minimize air pollution, entry of car park must be near as possible to Árpád bridge.

Noise protection

So it is strange, but suitable to develop transparent noise wall at south side of Árpád bridge which have its centre at ramp. That can have effect form viewpoint of air quality and noise protection. Implementation of a wall is depend from statics of a bridge.

Theoretically in case of Margit bridge (north side) must be a same noise wall required. But can be leave as compromise, because it is a historic monument.

Árpád bridge

Tram tracks must be make suitable for bus traffic. In that way most significant problem effect of traffic jam is solved.

To make possible turn to Isle the tram track must be opened at Isle. To help turn of bus it is suitable to build a tram protect type traffic light.

Stop of Népfürdő street must be modified in a way (because get off from bus), where safety island moved outer side of tracks. That is possible here. As result, get off become possible from tram and from trolleybus too.

Margit bridge

Tram tracks must be make suitable for bus traffic. In that way most significant problem effect of traffic jam is solved.

To make possible turn to Isle the tram track must be opened at Isle. To help turn of bus it is suitable to build a tram protect type traffic light.

To make possible turn the tram track must be opened at ramp of bridge. To help turn of bus it is suitable to build a tram protect type traffic light.

Stop of Jászai Mari square must be modified in a way (because get off from bus), where safety island moved outer side of tracks. That is possible here. As result, get off become possible from tram and from trolleybus too.

Ferenciek square (public traffic underpass)

Because requirement of trolleybus technology, underpass between Kecskeméti and Petőfi Sándor street must be deepen. It is possible here. Today’s technology can make detour using high pressure utilities.

Level of ventilation at underpass must be shifted to suitable level, because H_2 fuel technology (and for normal traffic too).

Rade Károly and Hazinszky Frigyes walkway

It is suitable to replace fragmented pavement (1,2km).

Public lighting must be replaced (1,2km).

Vajda Péter street

It is suitable to replace fragmented pavement (0,8km).

For route 99B final stop must be built at Petz Ármin and Rade Károly walkway.

Height of overbridge is a problem long ago. Therefore it is suitable to found solution. As result 99A “green” route can be extended to south.

Népliget M

At Ifjúsági walkway turn back must be built for two-axle buses. There have a place at cross of Ifjúsági and Hazinszky Frigyes walkway.

Which technology?

As consequence of conditions only less than 12.5m long well manoeuvrable two-axle bus can solve that problem.

We setup a flowing requirement for fuel and drive:

a) Reasonable operating cost,

b) Low (as possible to value provided by state of art) pollution,

c) Low internal and external noise.

Selecting fuel and drive need searching inquiry and due consideration, because requirement of environmental load.

We consider a following drives:

1) Diesel,
2) Biodiesel,
3) Hybrid,
4) LPG,
5) CNG,
6) Trolleybus,
7) H_2 combustion (H2-ICE),
8) H_2 fuel cell (FCH).

9) E-bus (use only battery as power-source)

How clean producing electricity determine environmental load of technology 6, 7, 8, 9. Load of environment near zero beside route (limited to noise). Selected drive just less clean than diesel engine, if for example selected vehicle type feed (directly or indirectly) by electricity which produced in diesel power plant. If electricity produced in natural gas power plant, then difference become significant. If electricity produced in hydro, wind, solar or nuclear power plant, then technology above become very clean.

Only technology 8 can be entirely clean (zero emission) technology. If its fuel (H_2) produced by clean energy, then is not load environment. Technology 7 have a same fuel, but entirely clean wrecked by high nitrogen oxide (NOx) emission and noise of combustion engine. Technology 9 can only clean, if charged by clean energy. Only way to do that, if "fuelling" done at time when clean energy available. Its meaning in practice, bus can charged only in garage. It is a way to make technology 6 and 9 clean, where clean energy stored and feed to system if required.

Technology 4, 5, 7, 8 require suitable (minimal) level of maintenance. It can be cause accident if not meet minima level (because financing reason or technical skill).

For isolated route technology 6 is uneconomical and hard to implement.

For technology 8, if difference is great in level between garage and route or for short route is not optimal.

Characteristic of technology 9 is relatively unsuitable mass-to-power and weight-to-power ratio. Other words, batteries take more place in cab, therefore inapplicable for heavy traffic route. Other disadvantage is a slow "refuelling". Advantage is easy to access "fuel" anywhere. Theory and practice point to, have best efficiency at flat country.

Because fuel's high energy density, technology 8 provide good mass-to-power and weight-to-power ratio. Experience of this technology shown, technology 9 optimal for "hobby-vehicle" (e.g. city passenger car), technology 8 is optimal for high output continuously operated vehicles (e.g. bus or often used taxi).

Besides good to know, battery of technology 9 must be replaced same frequently like fuel cells of technology 8.

Fall outs

Technology 1 and 2 fall out immediately because its heavy environmental load.

Technology 3 have smaller environmental load, but not proportionate to investment and expectations.

Technology 4 can be a compromise if project has sensitivity to initial costs. But because expectation are higher, then technology 4 and 5 and 7 is no optimal.

Conclusion

Consider all angle of technique and environment protection technology 6 trolleybus and 8 FCHBus suitable to serve routes of projects.

Hard to applicable technology 9 E-bus, because relatively unsuitable mass-to-power and weight-to-power ratio and long "refuelling" time. But because a special request and because significantly lower environment's load we try to fit that technology to project.

We can characterize Trolleybus technology as used for a long time. Application of significantly lower environment's load with near same operating cost.

We can characterize FCHBus technology as improvable technology of the future, which proved at dally usage. Application of lower environment's load near to zero with near same operating cost. Furthermore, possibilities of fuel production make it perfectly reliable source of power (used in for example vehicle) in case of exceptional situation.

Application of E-bus technology significantly lower environment's load with near same operating cost.

FCHBus technology must be examined from side of safety risk. That is explained at detail explanation of technology. From that viewpoint can applied without problem to route 26(A). Risk is acceptable if applying to route 15. In our opinion applying that technology for route 99 from that viewpoint is too risky.

As summary, if we consider technical, environment protection and profitability angle, then optimal solution for project is FCHBus and trolleybus. Using E-bus technology is less optimal, but with more compromise can be a solution. Because safety risk, using FCHbus for route 99A is not optimal.

See detailed explanation of technologies see below at chapters H_2 fuel cell (FCH) bus, E-Bus and Trolleybus.

H_2 fuel cell (FCH) bus

Generally

- Very clean technology.
- High energy density (120MJ/kg).
- High initial cost (vehicle acquisition).
- Require high level maintenance.
- Replacing fuel cell is permanent maintenance cost (* every ~4 year).
- Knowledge to operating this technology today available.
- Only need to build maintenance and refuelling facility.

* = By measuring at practice lifetime of fuel cell mostly depend form characteristic of usage. For example fuel cell grow old faster if vehicle just run more times over ten minute than 6-8 hour continuous operation in a day. In that way by practice lifetime for passenger car is 2500 hour (NREL: National Fuel Cell Electric Vehicle Learning Demonstration Final Report), for bus 10000 hour (AC Transit HyRoad Project, San Francisco Bay). In this manner for city buses 4 year replacing cycle can trust by practical experience.

How it works

Cheap hydrogen (H_2) produced by electrolysis using waste-to-energy of nuclear power plant. Source of hydrogen can be waste-gas which originating from decomposing process of natural gas. The produced hydrogen stored in tank.

Vehicle use hydrogen as fuel, its exhaust gas is clean water. Fuel stored in thank. That tank filled in hydrogen refuelling station / like well-known refuelling procedure /.

Vehicle itself drive by electric motor. Electricity produced by so called fuel cell (FCH) using hydrogen from tank and oxygen of open air. FCH hybrid can charge battery or supercap using energy of regenerative breaking. That energy can be used later for drive or operation of a vehicle (e.g. heating or air condition).

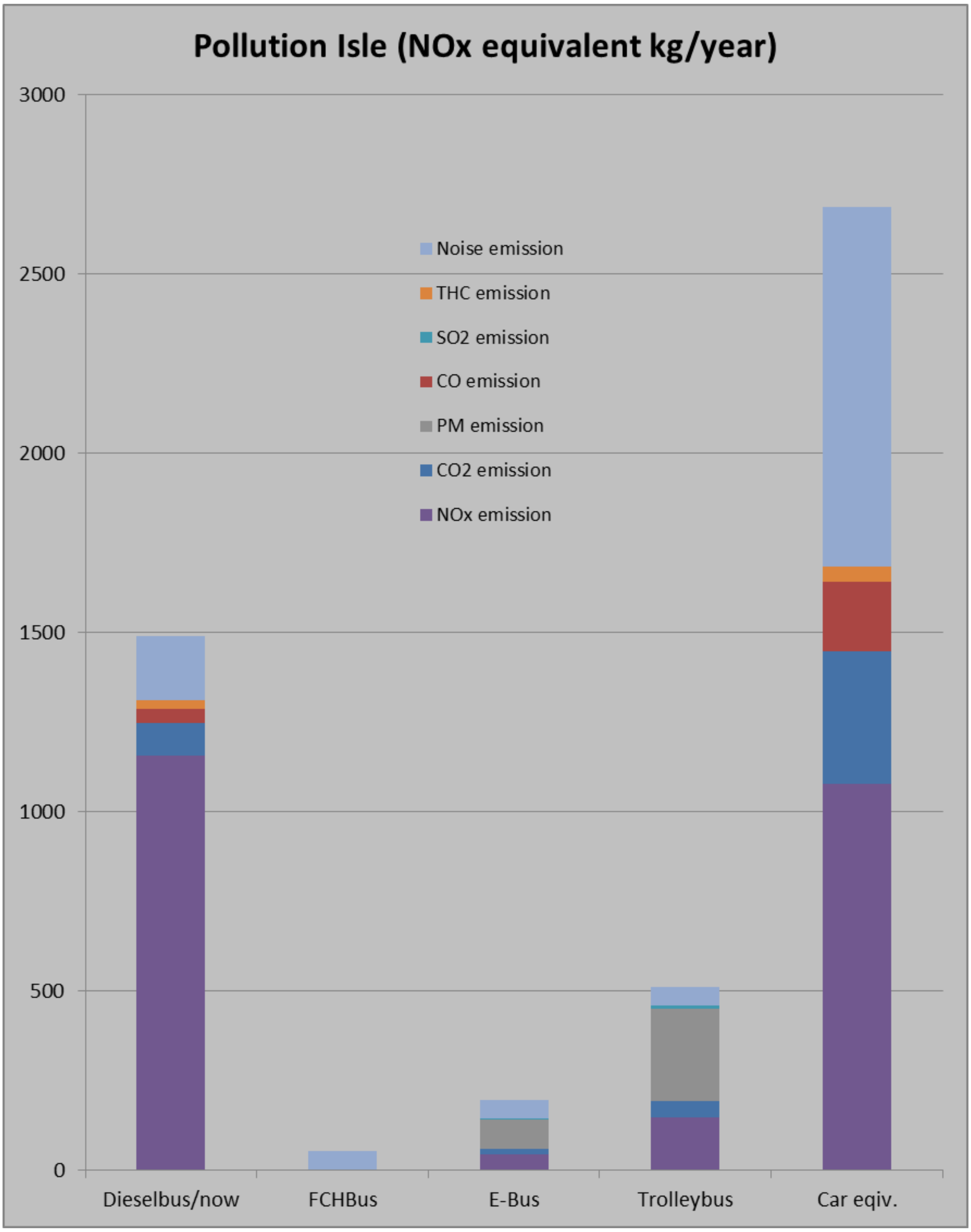
Explanation

Waste-to-energy: For some kind of power plant (e.g. nuclear) energy output just regulated slowly (because endurance). Therefore, output of power plant cannot adapt to quick change of consumption. That case, if everybody sleep at night, then energy consumption down dramatically. In that time output of power plant to a word spattered to air.

Hydrogen fuel cell (FCH): We can imagine that like a battery. We without interruption fill that battery with hydrogen and oxygen for air. As result we got battery never run down.

How far clean and environment-friendly

If we take all phase of technology into account, then that technology is exceptionally clean (real green), because not spread any kind of pollutant. Complete with green or waste-to-energy it is a most clean drive for public transport including horse tramway. To show that, we draw what will be amount of pollution if route 26 use a different kind of vehicle at isle Margit:



At left Column “Dieselbus/now” show present situation. Column “Car equv.” at right show what wold happen if route are cancelled, and everybody travel here with own car. Column “FCHBus” show pollution of hydrogen fuel cell bus. Be well worth seeing, that type of vehicle spread just a noise pollution.

National security considerations

H_2 fuel has environmental advantage. Furthermore have a special advantage, can be produced in many way using many elementary substance. H_2 fuel can produced with decomposing natural gas, decomposing water using electricity. Electricity can produced locally (using gas, oil, coal, water, wind). In that way provide continuous service in a situation where oil (import) unavailable. Moreover, if public transport which linked to electric grid are broken down (because if wind damage the electric grid), then H_2 fuel cell vehicle can provide continuous service.

Financing considerations

Most of fuel cell technology's initial cost originated from initial vehicle acquisition cost. In that way has no chance to financing this technology using national source. But if acquisition done using EU cohesion founds, then situation significantly changed. Shouldering of initial cost take this solution reachable.

If we observe maintenance cost, major part of them is periodic replace of fuel cells (from experience every 4 year). This can compared to fuel cost. Detailed calculation (using current and long term ratio of fuel costs) prove, high maintenance cost compensated by lower fuel cost. In that way total operational cost can be lower than operating cost of new diesel bus. Using waste energy significantly lower fuel cost compared to other environment friendly solution.

Technology considerations

Most important consideration is a minimum level of maintenance. LPG, CNG and H_2 technology require most disciplined maintenance than other technology. Of course specialist can work at this level, but many time company-owner hinder to do that.

Driving range is disadvantage of fuel cell technology, but in that project is not a real disadvantage. This is because fuel cell technology (instead of combustion) does not consume energy at stop or at traffic jam. Explained in simplified way, consumption is proportion to distance instead of duration. Other sides routes selected in a way, where route are relative short and difference of level are small. In addition fuel can get within 3 km distance from final stop. In that way refuelling is easy and quick.

Entirety, vehicle has 7 trip without refuelling for long (10km) route. In practice this is normal operation of a vehicle in a day (8 hour).

Same projects

Is a remarkable relation, company so called ACTransit in USA (kb. near Volán of Hungary) at city of SanFrancisco do experimental project with 3 FCHbus from year 2006. In year 2010 that project extended by ZEBA project to 12 bus. Target of that project is to serve part of seaside using green buses. This is very close to conception to server Margit isle with green buses. Other side is obvious, advantage and cleanness of that technology can be evident only if we experience it every day and every hour.

Tasks of codifier

H_2 fuel and its technology still unknown in Hungary. Therefor filling rules for taxation is still unsolved.

First task for codifier is fiscal classification of hydrogen fuel in a way where most clean fuel's tax can be less than cigarette's tax.

Other side classification of fuel cell still unsolved.

A third, law background must be fashion in a way, where prefer environment friend technology instead of penalty.

National resources

The H_2 technology in Hungary

Surprising, H_2 fuel cell technology applied in Hungary for not portable power source. Large quantities of H2 fuel produced at decompose of natural gas, but burned because useless.

Most important blockage to prevent usage H_2 fuel technology in a transport technology is a law background. This problem is only solved by codifier.

Production

At first sight we can think manufacturers of Hungary has no chance join to that technology. Instead of company Ikarusz produced 30 before city buses with near same CNG combustion and trolleybus. Fuel cell drive is mix of two technology above.

Development work done at city of Pécs in area of fuel cell technology by university and enterprise. The vehicle itself is near trolleybus of Transelectro (today Skoda), but use different powersource. So, Hungarian manufacturers have chance in open bidding.

Some part which cannot be produced with required quality can be imported as OEM product.

Remarkable, that technology need high level planning, production and quality assurance.

Operation

BKV has man of experience to operate trolleybuses. Tisza Volán has man of experience to operate CNG buses. Therefore national specialists can operate H_2 technology, because is mix of two technology above.

Vehicle

Requirements

Vehicle can comply with the flowing requirements:

a) Two-axle,

b) Maximum 13.5m long,

c) Well manoeuvrable,

d) H_2 fuel cell energy source,

e) 350bar storage tank;

f) Electric motor drive,

g) Can regenerative breaking (e.g. using battery storage),

h) Optimal weight,

i) Suitable safety,

j) Low tyre/road noise,

k) Comfortable acceleration and deceleration characteristic for standing passengers,

l) Low interior and exterior noise.

That type of vehicle engineered in way, where met requirement of 3.5m maximum height. For example height of IK260 are 3m, height of FCH buses are 3.4m.

Vehicle redirection

Redirection vehicles of this project are possible only with restrictions. Vehicles driving range are near 150km (without refuelling). Refuelling are limited to one place. For redirection take this two factor into consideration. Other side, load peaks can significantly reduce life cycle of fuel cell. In that way using fuel cell bus in mount related route can result increasing of maintenance cost.

Vehicle of other routes can redirect to that route without problem, if meet condition of environment protection.

Fuel production and refuelling station

Fuel cell technology require type I grade D better than 99.99% clean H_2 fuel.

Operating principle is, produce hydrogen at low current consumption period and store it onto fuel tanks. Content of that tanks ensure contiguous fuel supply at a day.

Suitable to produce H_2 fuel with electrolysis using water and waste-energy of nuclear powerplant. (theme of Hungarian FCH association). In that case it is possible, because electrolysis can stop or start near nay time. The produced hydrogen accumulated in storage tank.

Factory can build near to municipal sewage treatment plants of Csepel at riverside of river Duna. Because it is undeveloped area meet safety requirement.

Electricity available from Paks by transmission line. If low current consumption period occurred, then power plant or distribution can signal to factory.

Total H_2 consumption of vehicles near 308kg/day. This served by factory which has 2t/day H_2 production capacity (2 units of 2179,16 kW Electrolyser systems @ 50 kWh/kg H2 (44 kg/hr units)). In that way 4 hour waste-energy period ensure need for next day.

As alternative way, decompose of natural gas can produce clean hydrogen (but burned today because useless). Quality of that are 5.0, requirement are 3.8 for fuel cell. If its quality are meet requirement and its production is environment friendly, then can be used as fuel. That solution little bit complicated, because fuel must be transported to refuelling station (it is common for world).

Furthermore, if economic environment is convenient, then enterprise e.g. with 5 year concession can ensure fuel supply and refuelling system using one's capital.

Refuelling

Require 350bar refuelling station which can refuel truck-sized vehicles.

Impractical transport fuel to refuelling station, because H_2 factory near to city core. In that way refuelling station can work at gate of factory if keeping rules of safety regulation. Fuel here can available for anybody.

As alternative solution, refuelling can located in petrol station near to Weiss Manfréd street. Fuel can supplied using a pipe.

If we use location above for refuelling station as base, then routes selected in a way, where vehicles can refuel within 3km from final stop on the way to garage. This require near 1/50 fuel tank. Distance to refuelling for route 15 is 2.6km, for route 99 is 2.8km from final stop.

Later if that technology become common, then fuel can transported to any petrol station using for example tank-truck. In a present situation this is uneconomical.

Maintenance facility and garage

Basic requirement for maintenance facility and garage, here must not be any kind of spark. In that way trolleybus related facility is not a solution.

Bus garage Kelenföld

Dead mileage route for route 99 is path Könyves Kálmán, Szerémi, Etele, Tétényi, Hamzsabégi. Dead route is 6.2km long.

Dead mileage route for route 15 (26A) is path Soroksári, Könyves Kálmán, Szerémi, Etele, Tétényi, Hamzsabégi. Dead route is 6km long.

Distance from garage to refuelling is 5.8km.

To repair electrical failure specialist can make a short trip from trolleybus garage. To repair hydrogen technology suitable train local specialist. Exceptional refuelling can be possible at route or at garage using tank-wagon.

Bus garage Délpest

Dead mileage route for route 99 is path Könyves Kálmán, Gyáli, Nagykőrösi. Dead route is 6.3km long.

Dead mileage route for route 15 is path Soroksári, Kvassay, Könyves Kálmán, Gyáli, Nagykőrösi. Dead route is 8.7km long.

Distance from garage to refuelling is 8.4km.

To repair electrical failure specialist can make a short trip from trolleybus garage. To repair hydrogen technology suitable train local specialist. Exceptional refuelling can be possible at route or at garage using tank-wagon.

Safety

H_2 safety can definable as known in Hungary, because near same like CNG technology. Accordingly present expert knowledge and governmental regulation cover that technology.

Because CNG technology not used frequently, require to analyse safety in detail.

Fuel production factory

Suitable to build in isolated area.

Factory itself has more safety equipment, which prevent serious accidents (see NREL reports).

Refuelling station

Suitable to build in isolated area.

Refuelling station itself has more safety equipment, which prevent serious accidents (see NREL reports).

Maintenance

To operate that kind of technology is require high level of maintenance. Shortage of financing resources or skill can result serious accident. Therefore, use that technology must be suspended if level of maintenance is unsuitable!

Case of maintenance facility, there is no special risk if establishment and operation meet regulation.

Vehicles

Fuel stored in gas (gaseous) state at 350bar pressure. Tank is constructed by many small cylinder.

To detect leaking, vehicle has many preinstalled sensor. Computer process that information. If detect any problem, then immediately alarm or influence. For example, if detect leak at fuel cell, then secure valve of cylinders.

Fuel tank

Cylinders will be meet with hard test requirement.

Because its construction and material cylinders are very secure. Cylinder is elastic not brittle. Cylinder is not break. Elastically change its form without releasing fuel.

Cylinder is fire-proof within limits.

According some test result, if someone shoot into cylinder, then fuel just escape.

Fuel

However energy density of hydrogen (H_2) is very high, we got remarkable result compared to traditional diesel bus.

Weight of traditional diesel bus are 6 time higher than FCHBus. Traditional diesel bus take 2 time more fuel with than FCHBus. In case of accident, diesel fuel flow away and can be concentrate. Instead hydrogen fuel 16 time lighter than air, if escape, then quickly raise above buildings and disperse.

If we look to burning of burning, then diesel fuel flow away to any direction and can be set up fire lake. Because hydrogen lighter than air, at burning make well controlled flame like poplar wood. Therefore, if hydrogen fuel tank leaking and ignite at top of bus, then all passengers can be unharmed. We cannot say that for case of diesel fuel.

To ignite hydrogen require less energy than diesel fuel. But diesel fuel require quarter concentration to ignite than hydrogen. Because hydrogen quickly raise above buildings and disperse there, then concentration required to ignition mostly never happen.

To simplify, hydrogen fuel like CNG have risk only in closed space.

Accident risk

Most important risk is other vehicles. If a petrol vehicle collide with FCHBus, then no extreme danger of fire. Have problem only, if speed is extreme high or weight of petrol vehicle are high. Additional problem is, if petrol or diesel fuel flow away and ignite and heat hydrogen system over a long time.

I think everybody know police "hunting reality show", where crazy driver race through city at 180kmh, and then collide with one or more other vehicle. So, that is why North America afraid from that technology.

Unfortunately vehicles race through city using flash light belong to that group. For that viewpoint fire-fighter heavyweight vehicle is a most dangerous.

For subject route this is just a small problem. There heavy traffic is not typical, because formation of a streets race is impossible. Therefore, that factor is not a real risk for project's routes.

Leaking risk

It is not a major problem if fuel escape from FCHBus. Hydrogen quickly raise above buildings and disperse there, therefore never reach dangerous concentration. The problem is if hydrogen raise within high buildings in a narrow street. Hydrogen can concentrate in a room when window are open at summer.

Because quick raise of hydrogen, concentration required to ignition mostly never happen. In that way spark is not create problem within electric or overhead wire of public transport.

Using vehicle in closed space is not recommended. Reason for, leaking fuel can concentrate to dangerous value.

Sabotage risk

Not possible to protect system from guided explosion within cylinder of vehicle. In that case fuel of affected cylinder can really explode by mix oxygen of air. Power of that explosion multiplied by narrow street, high buildings and closed space. That is why FCHBus route keep away from that kind of built environment.

Hindenburg

If we say hydrogen, every people think to catastrophe of Hindenburg LZ129 at 1937. Maybe we never to known the truth, because this is endless political fight.

What is remarkable lesion, 65 person from 97 survive explosion? burning? of 2100m^2 hydrogen, just 35 died.

If we wish to compare, in case of LZ129 hydrogen stored in linen bag, in case of FCHBus stored in hardly tested composite cylinders. Energy density of fuel which stored in FCHBus is just 1 portent of LZ129's hydrogen set. If we do easy calculation, in case of FCHBus „LZ129" catastrophe number of dead is 35/100, can't be any dead.

Summary to related project

Fuel production factory planned to isolated area. In this way provide optimal security if any fire or explosion occurred.

Refuelling station planned to isolated area. In this way provide optimal security if any fire or explosion occurred. Because refuelling station neighbouring of fuel production factory therefore transporting fuel is not a risk.

Level of Maintenance skilled specialist can be available.

Vehicles meet strict requirement of international standards.

For subject routes Accident risk is not a problem. There heavy traffic is not typical, because formation of a streets race is impossible. Therefore, that factor is not a real risk for project's routes.

Route (e.g. 99) within high buildings in a narrow street Leaking risk and Sabotage risk can hit a high degree.

* * *

E-Bus

Generally

- Clean technology.
- High initial cost (vehicle acquisition).
- Replacing battery is permanent maintenance cost (* every ~4 year)..
- Knowledge to operating this technology today available.
- Only need to build maintenance and refuelling facility.

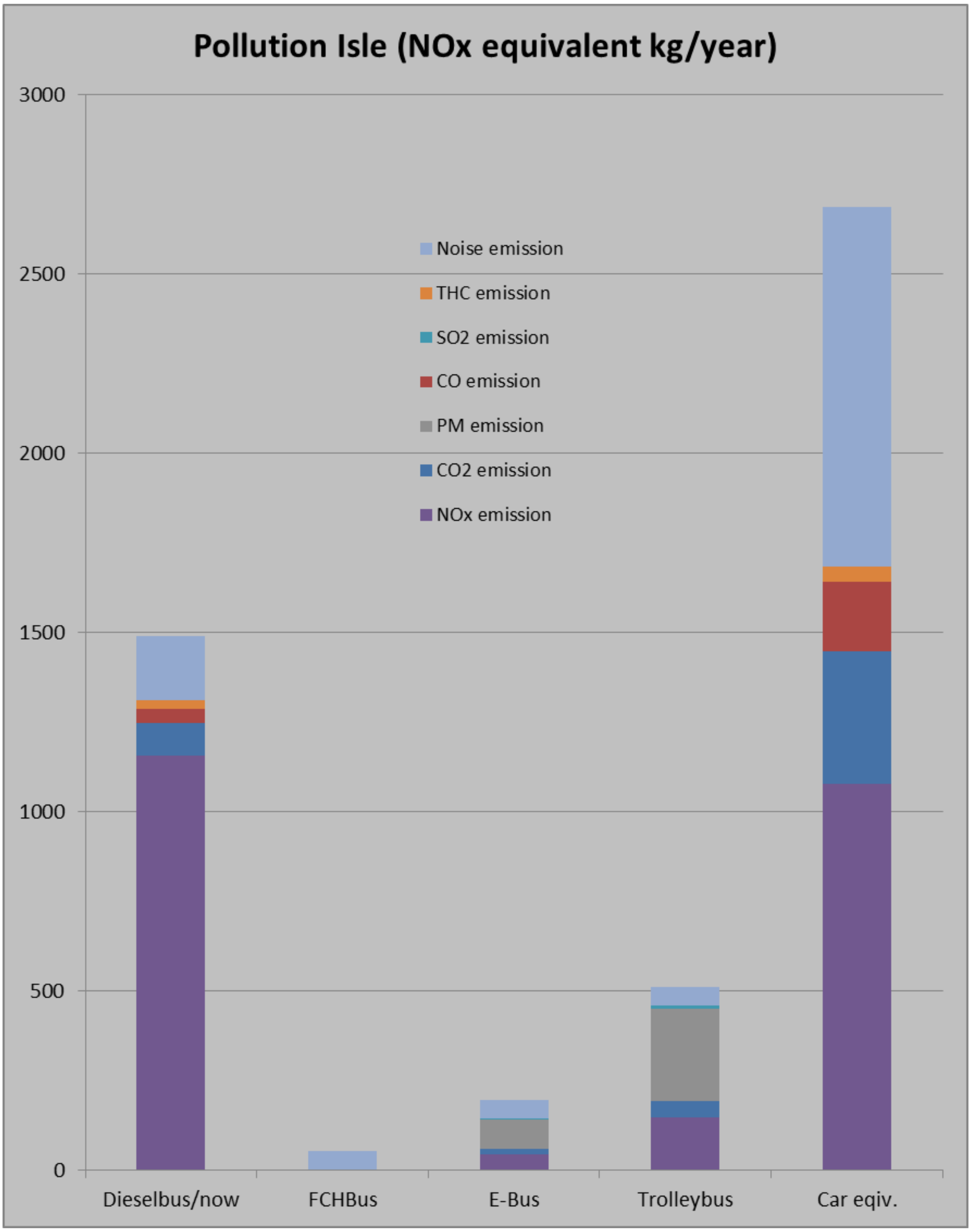
* = At that moment have no practical experience for city bus usage. Accessible BYD buses use BYD FE (Lithium Iron Phosphate LiFePO4) rechargeable battery. Life cycle of that type by manufacturer is 5000 cycle, by technical literature 1000-5000 ~= 2500 cycle (Magellan Power Lithium Iron Phosphate batteries – facts). If we count one charge in a day, then its life cycle near 6 year. But if route is hummocky, then life cycle be halved because regenerative breaking. That is why we count with near 4 year life cycle.

How it works

E-bus (full rechargeable battery powered bus) is electric motor drive vehicle. Its power source is more rechargeable battery. Charging of its battery done by special electric charger (electric refuelling station). Vehicle can charge battery using energy of breaking (regenerative breaking). That energy can be used later for drive or operation of a vehicle (e.g. heating or air condition).

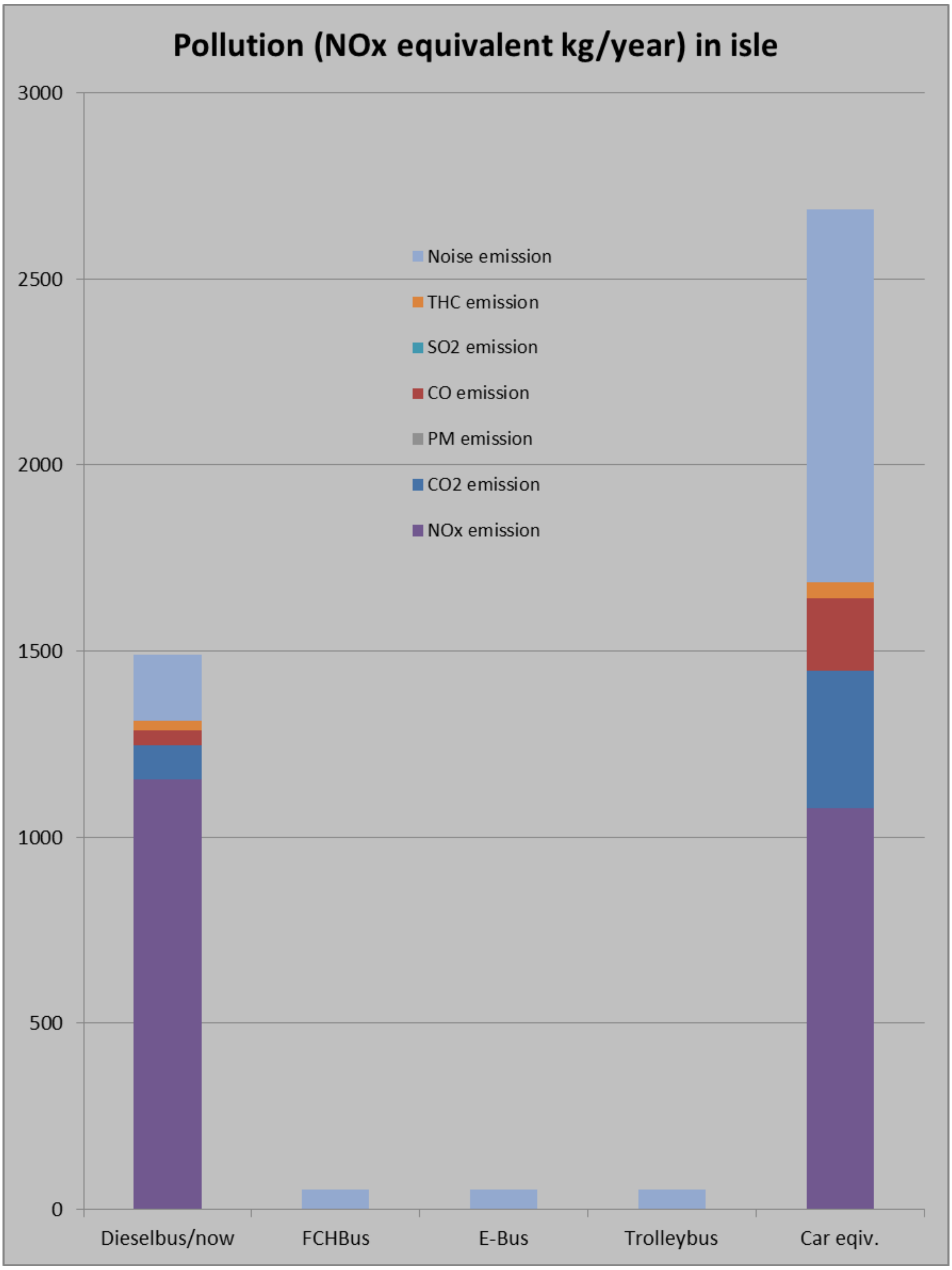
How far clean and environment-friendly

If we take all phase of technology into account, then that technology not spread any kind of pollutant. Its pollution generated only at producing its charging electric energy. To show that, we draw what will be amount of pollution if route 26 use a different kind of vehicle at isle Margit:



At left Column “Dieselbus/now” show present situation. Column “Car equv.” at right show what wold happen if route are cancelled, and everybody travel here with own car. Column “EBus” show pollution of E-bus. Be well worth seeing, pollution significantly lower if we change to that technology.

That diagram cannot show real advantage of that technology. Therefore we draw amount of pollution which really spread in Isle by vehicles:



That diagram show advantage of E-bus version. Globally that technology spread significantly lower pollution, but in Isle have just noise pollution. This is real reduction of pollution.

Financing considerations

Most of E-bus technology's initial cost originated from initial vehicle acquisition cost. In that way has no chance to financing this technology using national source. But if acquisition done using EU cohesion founds, then situation significantly changed. Shouldering of initial cost take this solution reachable.

If we observe maintenance cost, major part of them is periodic replace of rechargeable batteries (from experience every 4 year). This can compared to fuel cost. Detailed calculation (using current and long term ratio of fuel costs) prove, high maintenance cost compensated by lower fuel cost. In that way total operational cost can be lower than operating cost of new diesel bus. Using waste energy significantly lower fuel cost compared to other environment friendly solution.

Technology considerations

maintenance requirement of that technology is near same with requirement of trolleybus.

Disadvantage of rechargeable battery is relative short driving range and the long refuelling time. This is not real disadvantage for that project. For E-bus technology (selected) flat and relative short routes are ideal.

National resources

Production

That technology is near to trolleybus. That kind of vehicle can build base of trolleybus of Transelectro (today Skoda). Using national knowledge that bus can be better than original BYD, if have success to use BYD FE rechargeable battery as OEM product. That product can be saleable in European market.

So, Hungarian manufacturers have chance in open bidding.

Operation

BKV has man of experience to operate trolleybuses. National specialists can operate, because that technology is near the up-to-data trolleybus technology.

Vehicle

Requirements

Vehicle can comply with the flowing requirements:

a) Two-axle,

b) Maximum 13.5m long,

c) Well manoeuvrable,

d) Only rechargeable battery power source,

e) Electric motor drive,

f) Fast as possible recharge time,

g) Regenerative breaking,

h) Optimal weight,

i) Low tyre/road noise,

j) Comfortable acceleration and deceleration characteristic for standing passengers,

k) Low interior and exterior noise.

That kind of technology had been tested by BKV. That vehicle is a product with reachable price. Environment impact of E-bus technology (noise and pollution) much lower than emission of a car. In that way can use for route where street paved and it is enough wide.

Vehicle redirection

Redirecting vehicles of that project to other routes is possible if take speciality of technology into account.

Vehicle of other routes can redirect to that route without problem, if meet condition of environment protection.

Refuelling station

Fort that project refuelling (charge) available at all final stop. But must be take 3-4 hour „refuelling” time into consideration!

Maintenance facility and garage

Only requirement for maintenance facility and garage is, be near as possible to final stop of routes.

Trolleydepo

Here have today enough technical skill to store and repair vehicles.

Dead mileage route for route 15 (26A) is path Soroksári, Könyves Kálmán, Salgótarjáni. Dead route is 4,8km long.

Dead mileage route for route 99 is path Könyves Kálmán, Salgótarjáni. Dead route is 2km long.

Safety

Because this type of vehicle work using large quantities of battery, then its risk same like risk of rechargeable battery. Using Lithium Iron battery for vehicle is little bit dangerous, that is why less dangerous Lithium Iron Phosphate used instead. Risk of that type cannot exceed risk of liquid fuel (petrol) in case of accident or fire.

Trolleybus

Generally

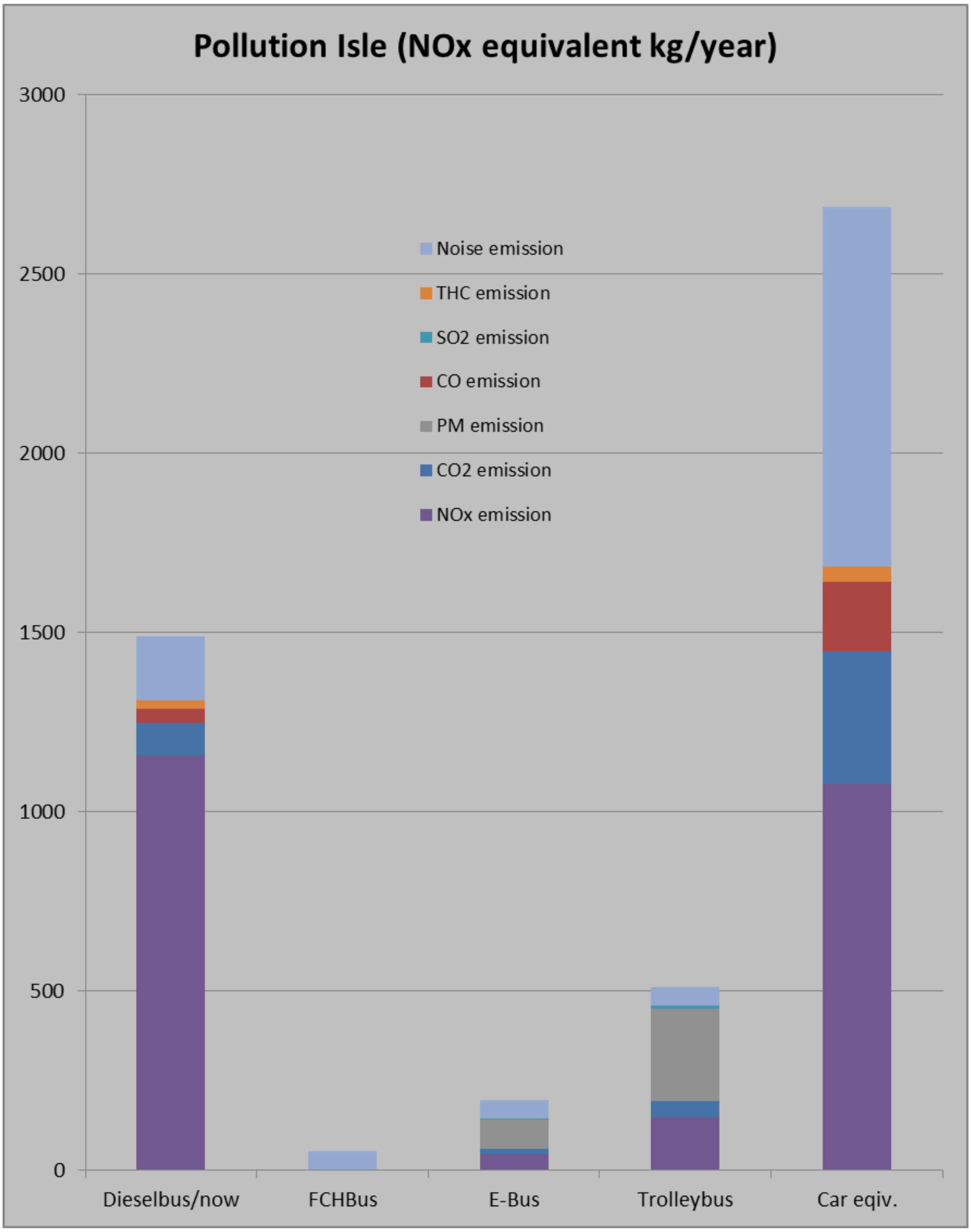
- Very clean technology.
- High initial cost (system build cost).
- Robust, wear well technology.
- Time-honoured professional experience.
- Relative cheap part acquisition.

How it works

Trolleybus is electro motor driven vehicle, which got its electric current „fuel" trough wire (overhead contact line). Vehicle can supply break energy to grid at breaking, in that way other vehicles can use it.

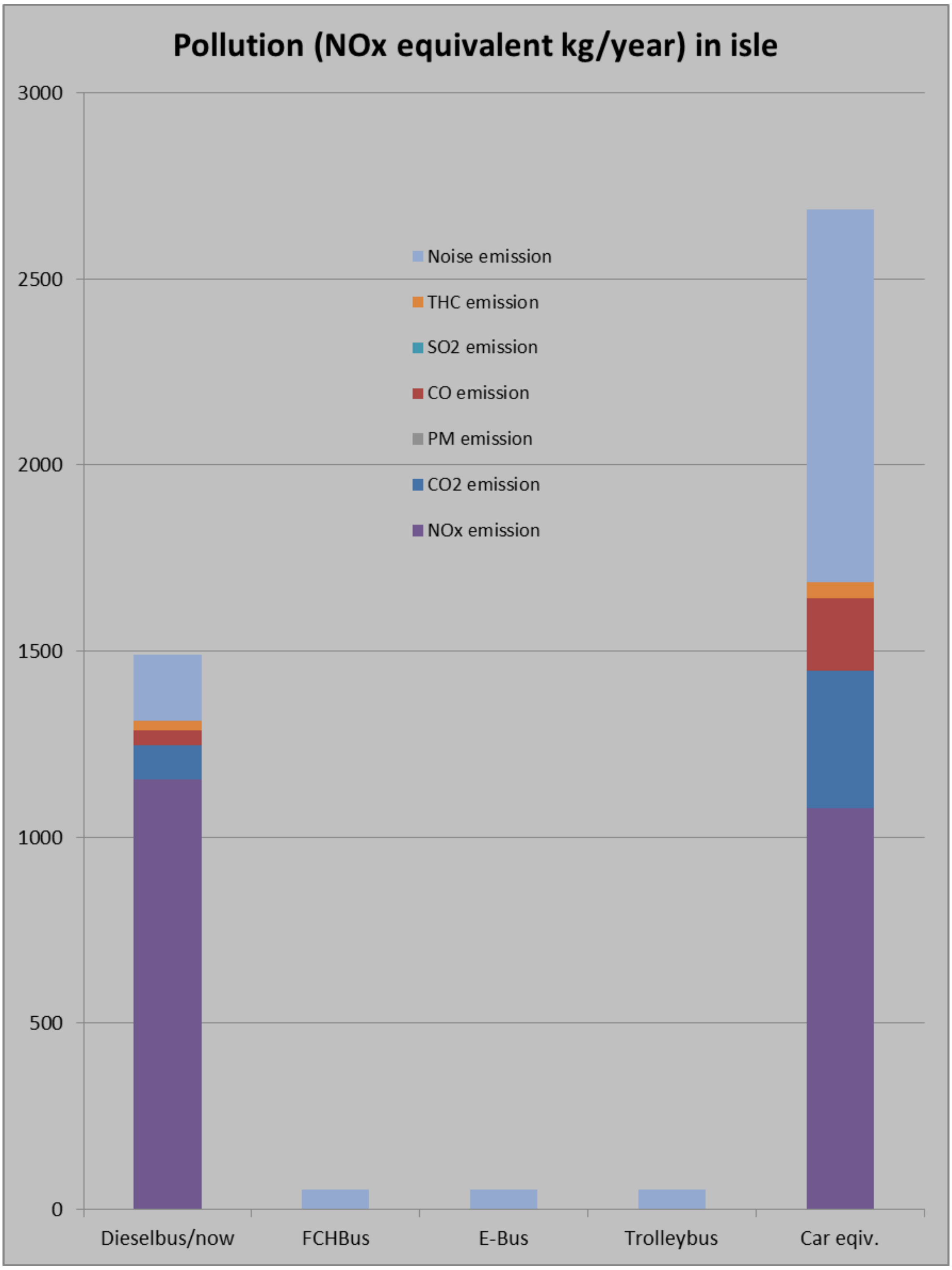
How far clean and environment-friendly

If we take all phase of technology into account, then that technology not spread any kind of pollutant. Its pollution generated only at producing its operating electric energy. To show that, we draw what will be amount of pollution if route 26 use a different kind of vehicle at isle Margit:



At left Column “Dieselbus/now” show present situation. Column “Car eqiv.” at right show what wold happen if route are cancelled, and everybody travel here with own car. Column “Trolleybus” show pollution of “old boy” trolleybus technology. Be well worth seeing, pollution significantly lower if we change to that technology.

That diagram cannot show real advantage of that technology. Therefore we draw amount of pollution which really spread in Isle by vehicles:



That diagram show advantage of Trolleybus version. Globally that technology spread significantly lower pollution, but in Isle have just noise pollution. This is real reduction of pollution.

Financing considerations

Most of Trolleybus technology's initial cost originated from system build cost. In that way has no chance to financing this technology using national source. But if acquisition done using EU cohesion founds, then situation significantly changed. Shouldering of initial cost take this solution reachable.

If we observe maintenance cost, major part of them is periodic system maintenance. This can compared to fuel cost. Detailed calculation (using current and long term ratio of fuel costs) prove, high maintenance cost compensated by lower fuel cost. In that way total operational cost can be lower than operating cost of new diesel bus. Using waste energy significantly lower fuel cost compared to other environment friendly solution.

Technology considerations

Trolleybus technology used often in Hungary over many decade. Its experts and supplier background make it easy to access. Because it is robust require no high level of maintenance.

National resources

Production

For that technology near century of experience to available.

Overhead wire production and installation work today.

Vehicle can be trolleybus of Transelectro (today Skoda). So, Hungarian manufacturers have chance in open bidding.

Operation

BKV has man of experience to operate trolleybuses. National specialists can operate that technology.

Vehicle

Requirements

Vehicle can comply with the flowing requirements:

a) Two-axle,
b) Maximum 13.5m long,
c) Well manoeuvrable,
d) Electric motor drive,
e) Regenerative breaking,
f) Optimal weight,
g) Reverse polarity protection,
h) Low tyre/road noise,
i) Comfortable acceleration and deceleration characteristic for standing passengers,
j) Low interior and exterior noise.

Vehicle is same like often used trolleybuses OF BKV. Because common tram-trolleybus overhead contact line, extra? requirement is a reverse polarity protection.

Vehicle redirection

Redirecting vehicles of that project to other routes is possible without any restriction.

Vehicle of other routes can redirect to that route without problem, if have reverse polarity protection.

Overhead contact line (overhead wire)

Árpád bridge

Common tram-trolleybus overhead contact line can build.

At Róbert Károly boulevard overhead wire can attach to public lighting's column.

Length: 1.3km, anchor to existing column.

Isle

At Margit isle overhead wire can attach to replaced public lighting's column.

Length: 2.2km, anchor to existing column.

Margit bridge

Can build a common tram-trolleybus overhead contact line. At turn in Buda overhead contact wire can attach by anchor to public lighting's column or wall. Because setup for tram trolleybus overhead wire have enough space below the bridge.

Length: 0.65km, to new column.

Szent István boulevard

At Szent István boulevard overhead wire can locked to wall using anchor.

Length: 0.4km, anchor to existing column or wall.

Path 15 N-S direction

At Honvéd street overhead wire can locked to wall using anchor.

Length: 0.65km, anchor to wall, one direction.

Can be attached to Kálmán – Kozma – Kossuth existing overhead wire.

Length: 0.15km, existing, one direction.

At Nádor street overhead wire can locked to wall using anchor.

Length: 0.75km, anchor to wall, one direction.

At József nádor square overhead wire can locked to wall using anchor.

Length: 0.13km, anchor to wall, one direction.

At Szende Pál street overhead wire can locked to wall using anchor.

Length: 0.17km, anchor to wall, one direction.

At Apáczai Csere János street overhead wire can locked to wall using anchor.

Length: 0.32km, anchor to wall and columns, one direction.

At Petőfi square overhead wire can locked to public lighting’s column using pole.

Length: 0.1km, pole to existing column, one direction.

At Március 15 square overhead wire can locked to public lighting’s column using pole.

Length: 0.12km, pole to existing column, one direction.

Belgrád quay overhead wire can locked to wall using anchor, to public lighting’s column or to tram’s existing girder wire.

Length: 0.55km, anchor to wall and existing columns, one direction.

At this stage of Fővám square #1 overhead wire can locked using pole.

Length: 0.05km, pole to existing column, one direction.

At this stage of Fővám square #2 overhead wire can locked to wall using anchor, to public lighting’s column or to tram’s existing girder wire.

Length: 0.1km, anchor to wall and existing girder wire, one direction.

At Vámház boulevard overhead wire can locked to wall using anchor, to public lighting’s column or to tram’s existing girder wire.

Length: 0.22km, anchor to wall and existing girder wire, one direction.

At Kálvin square overhead wire can locked to wall using anchor, to public lighting’s column or to tram’s existing girder wire. recommended to extend overhead wire to link of Közraktár and Üllői street.

Length: 0.18km, anchor to wall and existing girder wire, one direction.

At Ráday street overhead wire can locked to wall using anchor.

Length: 0.9km, anchor to wall, one direction.

At Boráros square new columns must be installed, overhead wire attached to pole.

Length: 0.1km, new column with pole, one direction.

Path 15 S-N direction

At Közraktár street new columns must be installed, overhead wire attached to pole.

Length: 0.25km, new column with pole, one direction.

At Bakáts street overhead wire can locked to wall using anchor.

Length: 0.1km, anchor to wall, one direction.

At Lónyai street overhead wire can locked to wall using anchor.

Length: 0.7km, anchor to wall, one direction.

At Kálvin square overhead wire can locked to wall using anchor, to public lighting's column or to tram's existing girder wire.

Length: 0.18km, anchor to wall and existing girder wire, one direction.

At Kecskeméti street overhead wire can locked to wall using anchor.

Length: 0.6km, anchor to wall, one direction.

At Petőfi Sándor street overhead wire can locked to wall using anchor.

Length: 0.3km, anchor to wall, one direction.

At Szervita square overhead wire can locked to wall using anchor or to public lighting's column.

Length: 0.1km, anchor to wall and column, one direction.

At Bécsi street overhead wire can locked to wall using anchor.

Length: 0.2km, anchor to wall, one direction.

At Erzsébet square overhead wire can locked to wall using anchor or to public lighting's column.

Length: 0.27km, anchor to wall and column, one direction.

At Október 6. street overhead wire can locked to wall using anchor.

Length: 0.35km, existing, one direction.

At Arany János street overhead wire can locked to wall using anchor.

Length: 0.3km, existing, one direction.

Vadász street existing final stop for trolleybus.

Length: 0.1km, existing, one direction.

At Bank street overhead wire can locked to wall using anchor.

Length: 0.1km, anchor to wall, one direction.

At Hold street overhead wire can locked to wall using anchor.

Length: 0.4km, anchor to wall, one direction.

At Kálmán Imre street overhead wire still exist.

Length: 0.05km, anchor to wall, one direction.

At Szemere street overhead wire can locked to wall using anchor.

Length: 0.6km, anchor to wall, one direction.

Path 15 turn backs

For route’s south part practical to build turn back at Szabadság square. That turn back can build at Szabadság square between Hold and Nádor street. If demonstration occurred ensure traffic of route’s south part. There overhead wire can attached to pole.

Length: 0.3km, new column with pole, one direction.

At Markó street between Honvéd and Szemere street turn back must built. If demonstartion occured ensure traffic of route’s north part. This turn back ensure to operate a short route at night and weekend / when north part have higher load /. New columns must be installed, overhead wire attached to pole.

Length: 0.1km, new column with pole, one direction.

At Vámház boulevard natural turn back established, therefore not required to build.

Length: -

99

At Blaha Lujza square overhead wire can locked to tram’s existing girder wire.

Length: 0.1km, anchor to wall and column, one direction.

At Népszínház street #1 overhead wire can locked to tram’s existing girder wire.

Length: 0.3km, anchor to wall and existing girder wire, one direction.

At Rákóczi street overhead wire can locked to pole which attached to public lighting’s column.

Length: 0.25km, pole to existing column, one direction.

At Kiss József street overhead wire can locked to wall using anchor.

Length: 0.32km, anchor to wall, one direction.

At Népszínház street #2 overhead wire can locked to tram’s existing girder wire.

Length: 0.15km, anchor to wall and existing girder wire.

At Nagy Fuvaros street overhead wire can locked to wall using anchor.

Length: 0.31km, anchor to wall.

At Mátyás square overhead wire can locked to pole which attached to public lighting's column.

Length: 0.2km, new column, anchor.

At Szerdahelyi street overhead wire can locked to wall using anchor.

Length: 0.31km, anchor to wall.

At Karácsony Sándor street overhead wire can locked to wall using anchor.

Length: 0.42km, anchor to wall.

At Kálvária square existing overhead wire, need to build/repair because just one direction.

Length: 0.2km, anchor to wall.

At Diószeghy Sámuel street existing overhead wire, must be repaired.

Length: 0.15km, anchor to wall.

At Kőris street overhead wire can locked to wall using anchor.

Length: 0.3km, anchor to wall, one direction.

At Orczy street overhead wire can locked to tram's existing girder wire.

Length: 0.18km, anchor to wall and existing girder wire.

At Vajda Péter street #1 (from Orczy street to Könyves Kálmán boulevard) overhead wire can locked to wall using anchor. At stage liget overhead wire can locked to public lighting's column. Remark: not long ago that was tram route, therefore hooks must be here.

Length: 0.85km, anchor to wall and column, one direction.

At Vajda Péter street #2 (from Könyves Kálmán boulevard to Petz Ármin walkway) overhead wire can locked in both side of street to existing public lighting's column.

Length: 0.7km, anchor to existing column.

At Petz Ármin walkway overhead wire can locked in both side of street to existing public lighting's column.

Length: 0.1km, anchor to existing column.

At Rade Károly walkway overhead wire can locked in both side of street to existing public lighting's column.

Length: 0.6km, anchor to existing column.

At Hazinszky Frigyes walkway (Népliget M) overhead wire can locked in both side of street to existing public lighting's column.

Length: 0.6km, anchor to existing column.

Path 99 turn backs

At Kálvária square natural turn back established, therefore not required to build.

Length: -

Current supply

Current supply can be done by tap supply of tram lines. Is not necessary to build a new power station, but for sure included to project's budget.

Dead mileage

Route to garage ensured, because new overhead contact line has link to existing system.

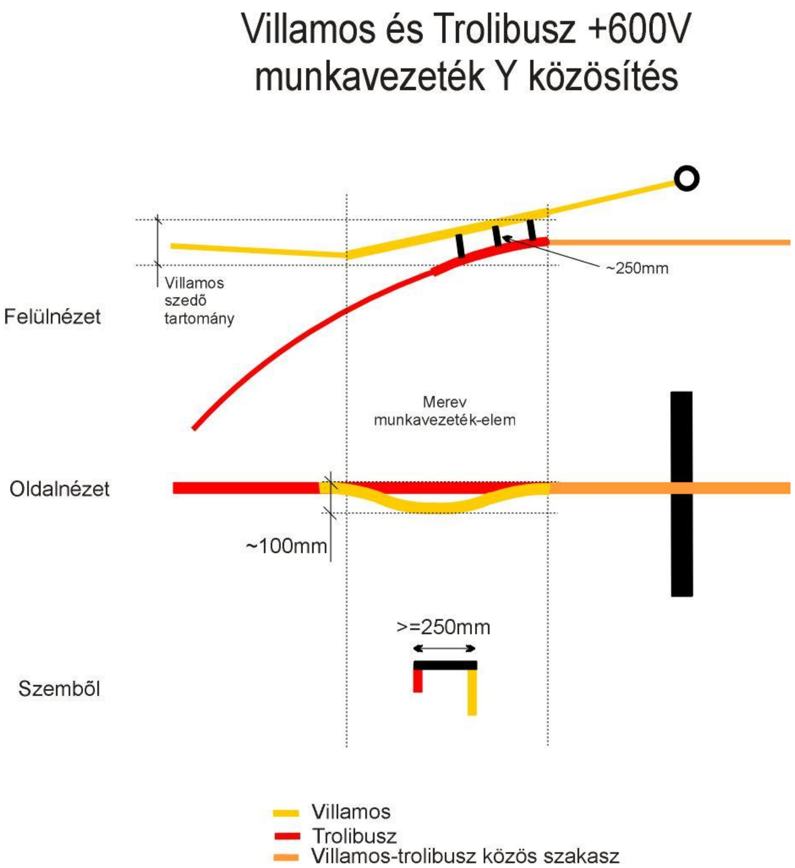
Common tram-trolleybus overhead contact line

Come up against a difficulty to lock overhead contact wire at bridges mainly in Margit bridge. Actual renovation forgot to think about. Of course, if three wire can attached for each direction then nothing to do. If not, then some innovative solution required.

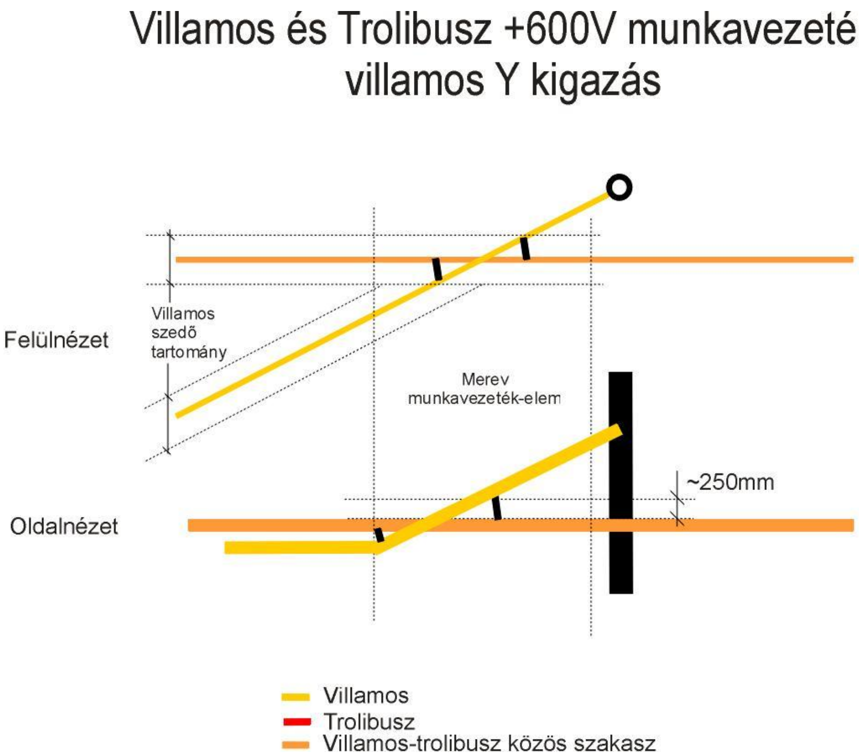
If just two wire can attached for each direction (e.g. because its weight), then come up solution common +600V tram-trolley overhead contact wire. In theory no trouble at all, curve rail can used.

Significant difference is while tam use just one side of wire, trolleybus use three side of wire. Only need to do to build overhead contact wire according rule of trolleybus. Moreover, vehicle sensor must be attached in a way where applicable for tram and trolleybus current collector.

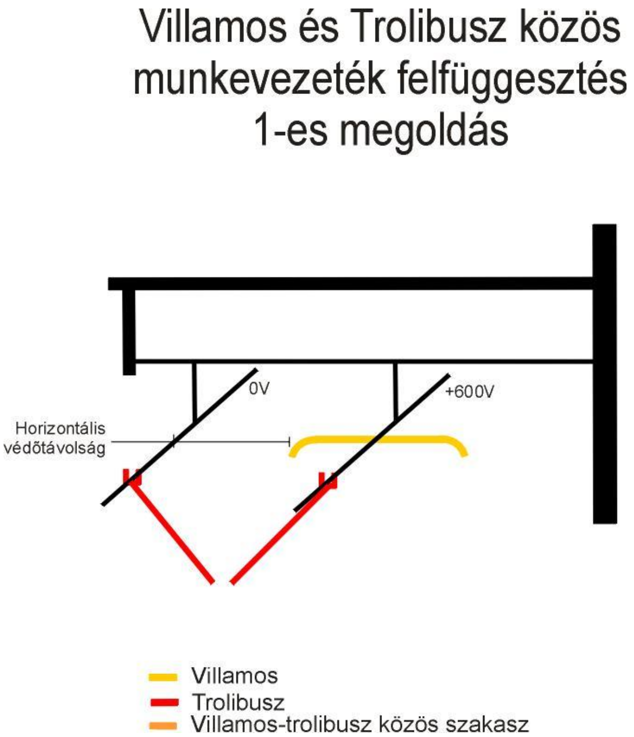
Trolleybus Y type overhead contact wire connection to tram-trolleybus overhead contact wire can be solved using special X curve rail. Solution shown by draw above:



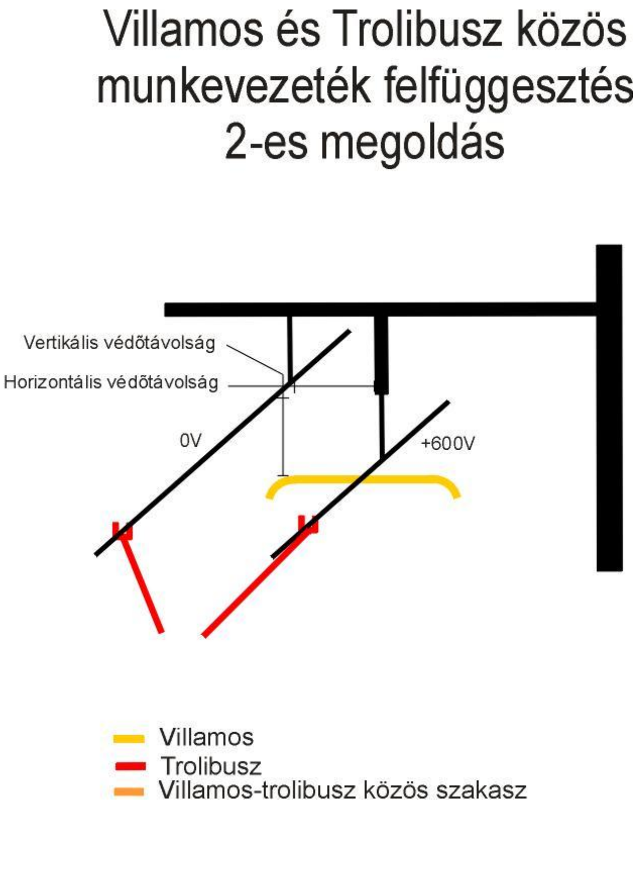
Tram Y type overhead contact wire connection from tram-trolley overhead contact wire can be solved using special X curve rail. Solution shown by draw above:



Need a special looping method to locating 0V wire. If that wire cross by tram overhead wire (e.g. case Tram Y type overhead contact wire connection from tram-trolley overhead contact wire), then require half of normal trolley-tram crossing. One possible solution shown by draw above:



In solution above height of tram-trolleybus +600V 0V overhead contact line are same. Trolleybus 0V line attached in a way, where sure outside operating range of tram's current collector. Two line separated by horizontal safety distance.



In solution above height of tram-trolleybus +600V overhead contact line is lower than 0V line. The +600V line locked by girder (e.g. inflexible pipe) at lower height. Two line separated by horizontal and vertical safety distance.

Maintenance facility and garage

Trolleydepo

That new routes have overhead contact line to Trolleydepo. Here have today enough technical skill to store and repair vehicles.

Dead mileage route for route 15 (26A) can be done using dead mileage route of route 70.

For route 99 can be done using dead mileage route of route 83.

Safety

Experiences shows, that technology has no significant security risk.

Development possibilities

FCH technology

Bring up many new possibility if FCH (hydrogen fuel cell) version implemented.

Public refuelling station

Refuelling station build by that project is a first one in Hungary. Can produce, store and refuel (together with hydrogen factory) 250kg in a day at very low price (3,5USD/kg), and can additional 1500kg at low price (4,5USD/kg). Its capacity can multiplied with ten in economic way.

Hydrogen fuel ship

Because rive Duna is near, that project can supply hydrogen fuel for ship. It can provide clean and environment friendly power source for small to large ships, because can used for combustion and fuel cell too.

Peaking power plant

Hydrogen produced by project's factory can used in a middle sized hydrogen power plant. We produce hydrogen in a cheap period, and in consumption peak we produce electricity using hydrogen fuel, and feed it into grid.

Because exchange rate, tax, subvention and law environment in Hungary are unsure, therefore contiguous recalculation of profitability needed.

Reduce fuel cost of Budapest's electricity based public transport

In Budapest some of public transport user electricity as fuel. Unfortunately traffic peak of public transport are in same period like consumption peak at electric grid. Using conception Peaking power plant can supply cheap electricity for all public transport in consumption peak. This can be implemented in a way, where hydrogen pealing power plant supply its energy to grid.

Because exchange rate, tax, subvention and law environment in Hungary are unsure, therefore contiguous recalculation of profitability needed.

Project financing

That project can considered as complex environment protection project, because target environment protection. Its basic project part is significantly reducing environmental load at Margit isle. Its major linked project part is target near the same for inner town. In that way can be European pilot-project, which provide model for many other city. In that way MSziget-15-99 project can realizable by significant EU financing part.

Why Msziget-15-99

Unfortunately we can say, there no other route where can possible significant reduction of environmental load. For near all other route public traffic's environmental load exceed public transport's environmental load. There reduction of public transport's environmental load not provide significant result.

Only exception form is area of Széll-fogas project and route family 7 which replaced by metro line 4.

Other side, that technology can cut public transport's environmental load at all suburb route of BKV. Unfortunately its financing resource requirement is so high, EU resources it would not be enough for.

Explanation of EU finance

In Hungary position of environment protection in all walks of life (transport, heating, waste handling, health) are saddening. Other words, we can meet in environment protection culture the biggest cohesion distance between Europe and Hungary.

Its iconic example is a 26-15-99 problem, which cannot solved in past near 50 year using own resources and will of country. Maybe only way to solve that problem is using EU cohesion founds.

In that way to an improvement if EU help by directives and cohesion founds to realize iconic projects, which set an example for country which close up to the ranks.

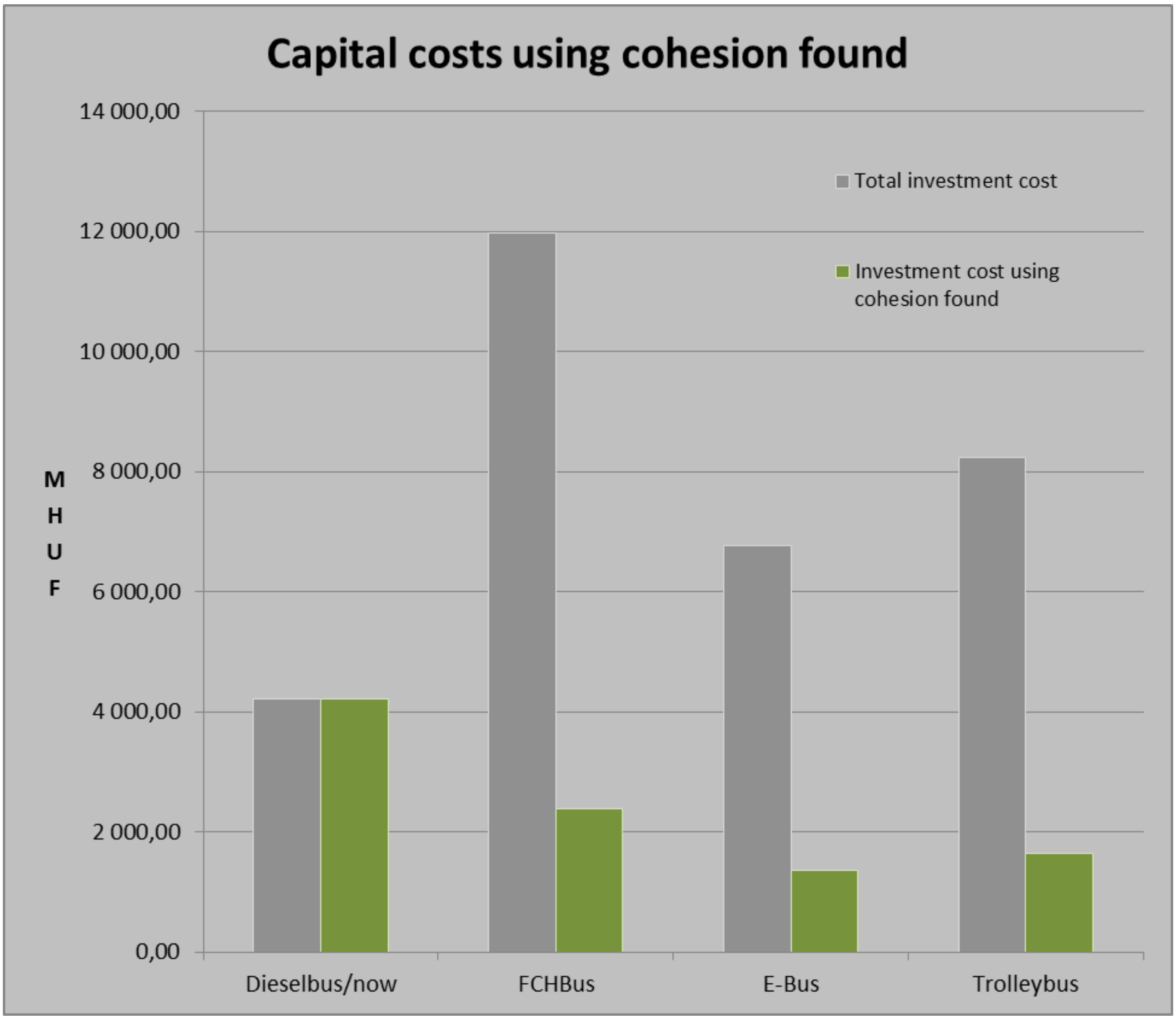
It is remarkable, if fuel cell FCH version selected, then that project can join to CHIC (Clean Hydrogen in European Cities) and to HyFLEET: CUTE project. This help to materialize that project, and can capitol city can be promoted.

Financing is possible because Article 2 1b rule to use cohesion founds.

And finally we must dispel an public belief. Some responsible people say, not possible to use EU cohesion found to buy a bus for public transport. This is true for often used vehicles in Hungary which have significant environment pollution. Instead EU support production and acquisition of significantly environment friend buses. In that way acquisition E-bus or FCHBus possible using EU cohesion found resources. To do that minimum require to know environment friend technology and possibilities.

Investment costs

Some people say, for that high „jump" require immensely more financing resources. But if we use well our chance, then no additional resource required. Other words, if cohesion resources spend in a way which is its primary function, then we are capable to make a good score. To understand that, we show diagram, which results of complex calculation and analysis:



Distinctly visible, without cohesion found replacement of vehicle fleet to environment friendly is much expensive (grey columns). If we do replacement of vehicle fleet together with replace to significantly environment friendly technology, then we can buy two very environment friendly bus for price of one new diesel bus. Remarkable, this include cost of infrastructure build-up. Therefore, very environment friendly technology has half price (including infrastructure build-up) than traditional technology!

FCHBus

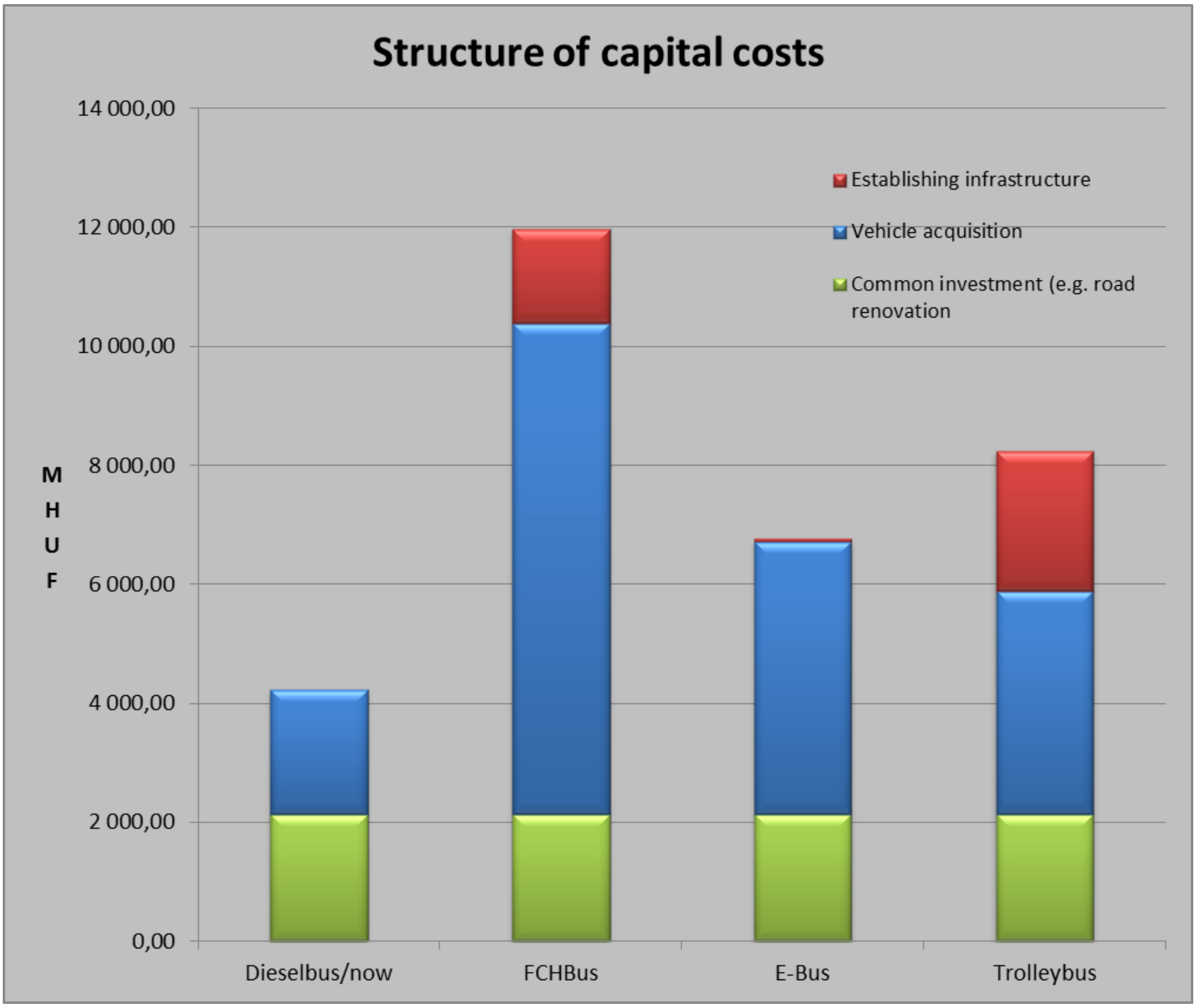
Because in Hungary today no H_2 factory exists, its build cost included to that project. But ”product” (H_2) of that factory can be sell as commercial product, then part of investment can be refunded.

Covered car park at Isle

We got some kind of feedback, financing build of covered car park at Isle is not possible (1.5MrdHUF). After some recount cleared up, income of that car park in a year is near 0.5MrdHUF and its outlay near zero. Therefore, that subproject can financed by parking charges (recovered over 3 year), if have no chance to financing by cohesion founds.

Cost structure of investment

Diagram below show cost structure of investment without:



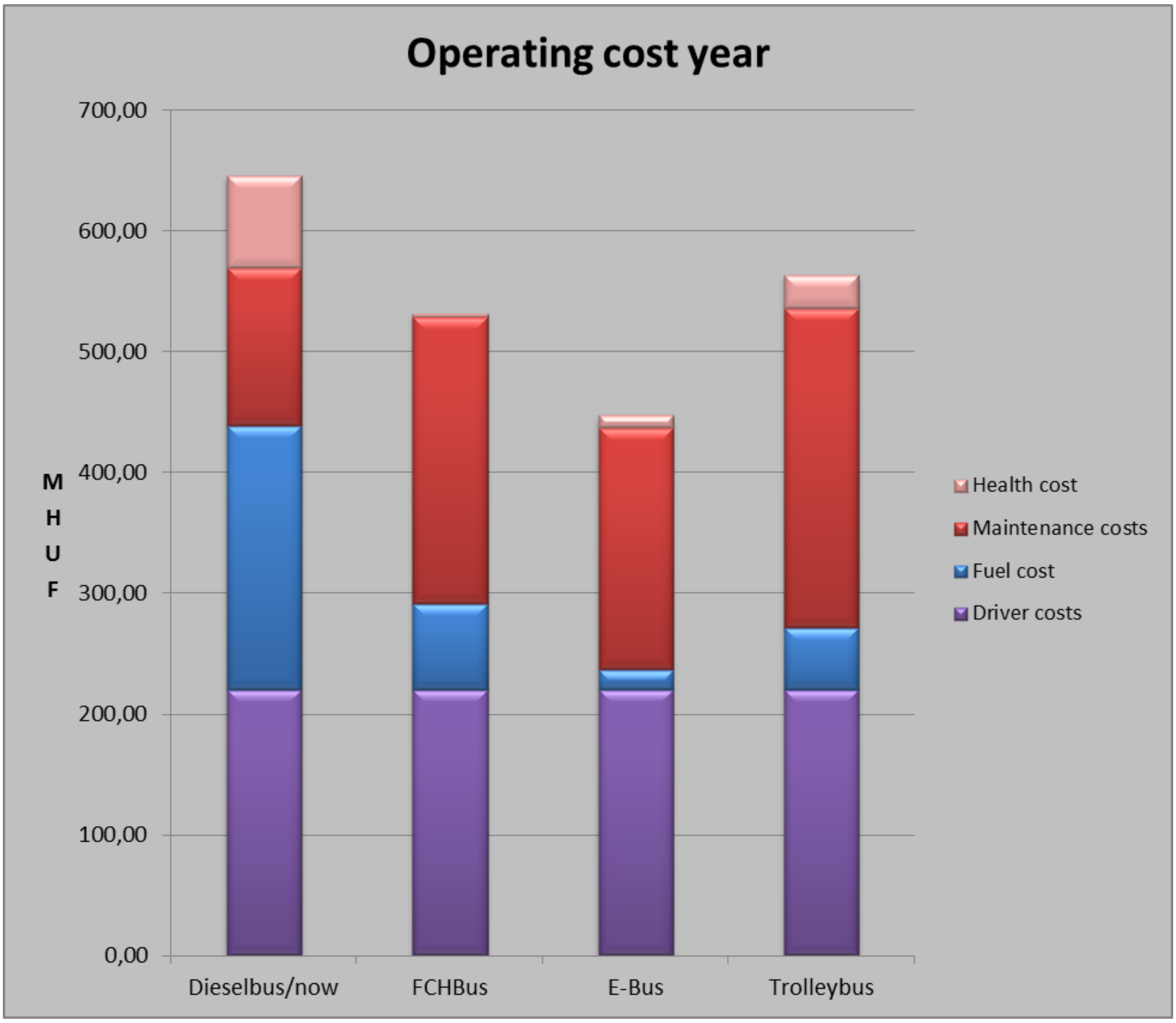
There aquisition of vehicles is dominant. FCHbus is a most expensive according international experience. In taht special case trolleybus system build cost can comparable to vehicle acquisition of FCHBus. Aquisition cost of E-bus significantly high than trolleybus. If we make use of cohesion founds, then structure of investment is not changed, but prime cost significantly decrease. See chapter Investment costs for detail.

Covered car park at Isle is dominant for common invesment cost. See chapter Covered car park at Isle for detailed explanation.

Effects and result

Economic

To show economic effect, we summarize costs and its components in a diagram:



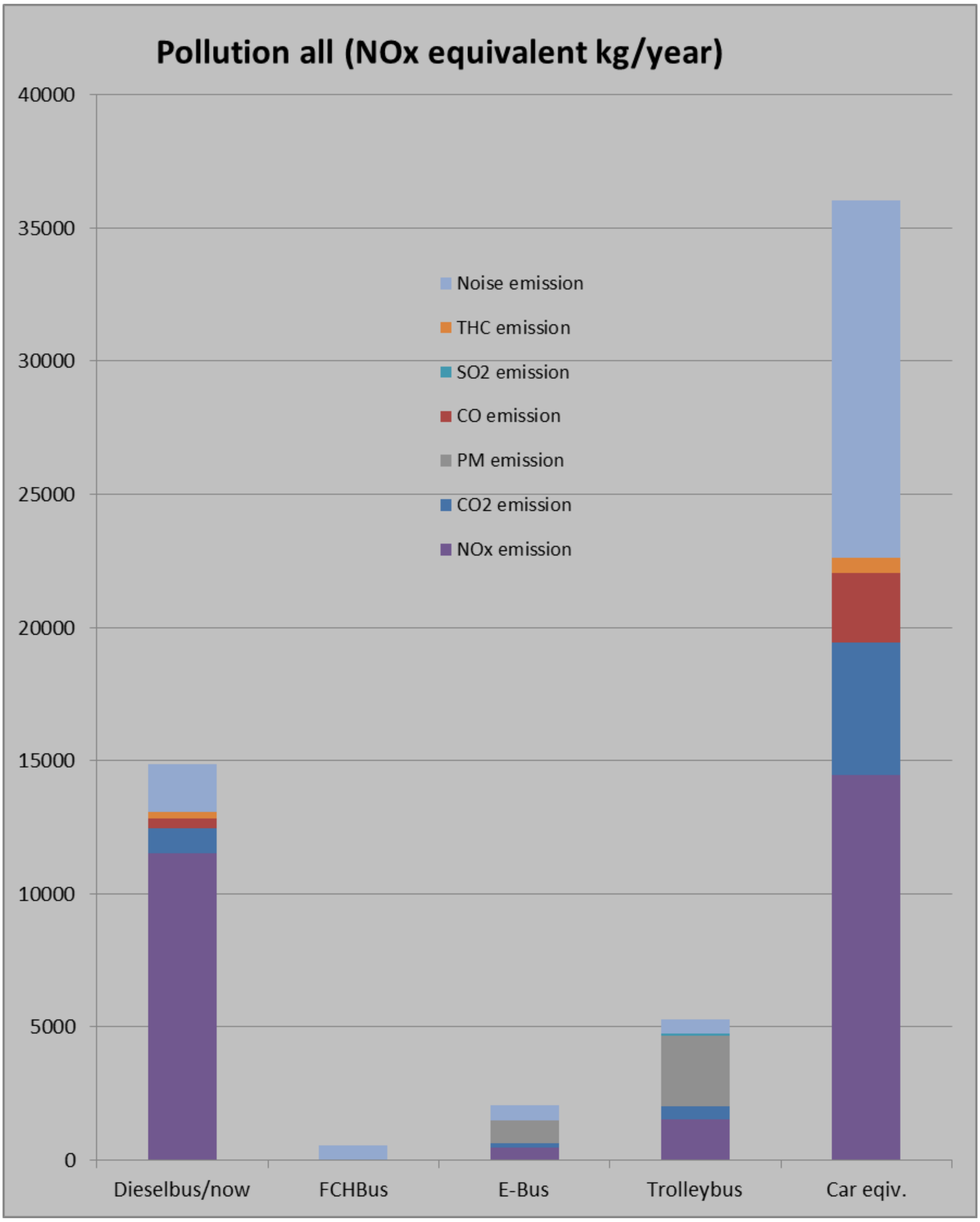
That diagram show, using environment friendly technology not increase, just the opposite reduce operating costs. It is true for case too, where in a „eastern Europe way" subtract health cost from. Improvement of technology decrease fuel cost, but increase maintenance cost.

Remarkable, maintenance cost of FCHbus little bit higher than Ebus, but for that cost FCHbus have significantly lower environmental load. See chapter Environmental for details.

Remarkable, there is no practical experience abut Ebusz technology. Therefore results based on technical specification of manufacturers and based on technology related calculation!

Environmental

To show environmental impact we recalculate it to nitrogen oxide (NOx) equivalent value, and then draw pollution of all related route for one year period to a diagram:



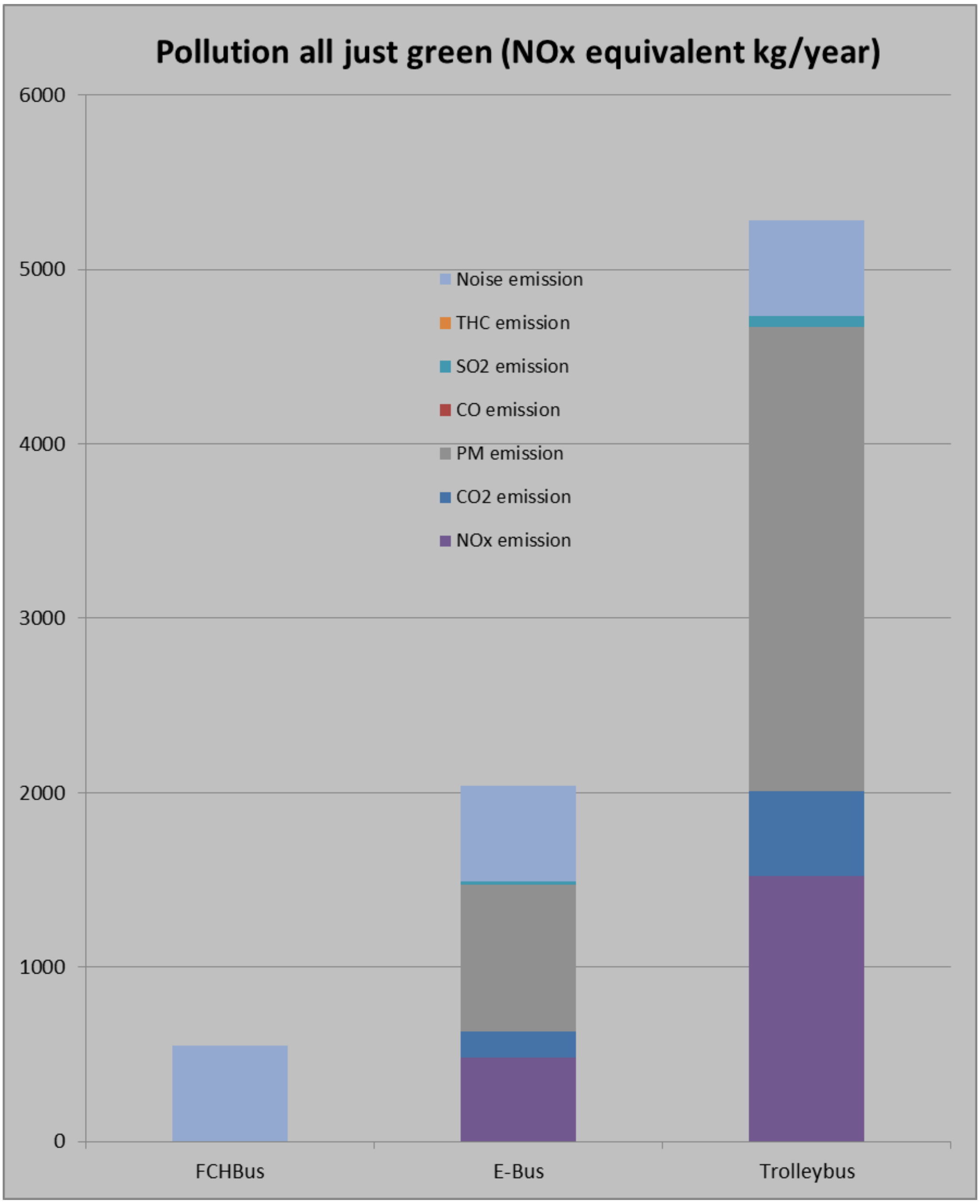
There distinctly visible, NOX equivalent pollution of related route for today's diesel bus is ~15000kg/year. Remarkable, it is more optimist than reality, because calculated with better buses than BKV's vehicles.

There is no any kind of measuring data for today's old IK buses. It follows from pollution in a real world is (significantly) higher than ~15000kg/year.

But it is a luck, because if peoples can use car here instead of bus, then pollution can increased to ~36000kg/year.

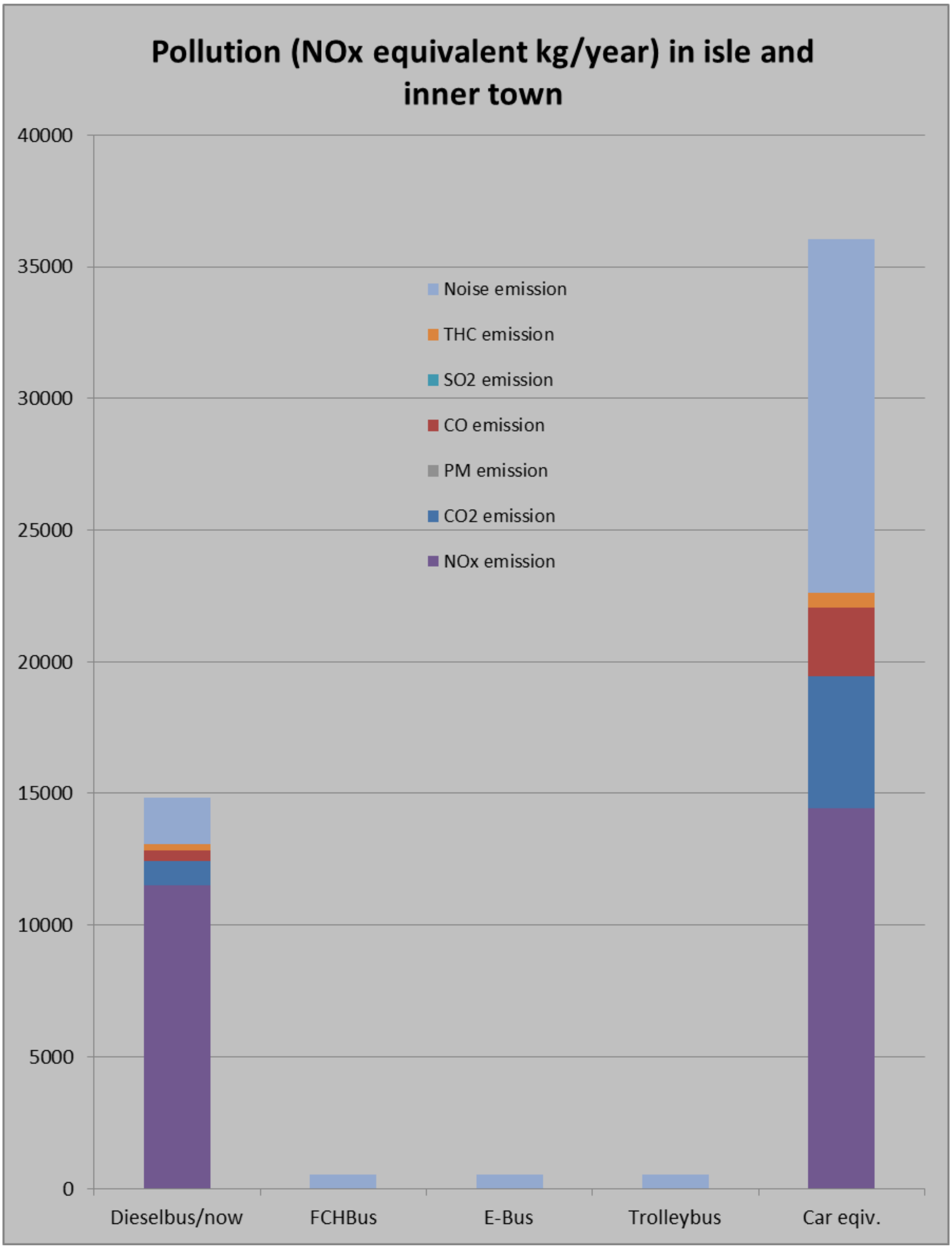
Most important thing is, trolleybus, Ebus and FCHbus significantly decrease pollution. Trolleybus (because power plant) to tenth to ~5000kg/year. Ebus to little bit lower value to ~2000kg/year, which is significantly higher than FCHbus. FCHbus pollution (because usage of nuclear power plan waste energy) only noise at ~500kg/year.

Because a difference is very significant good to environment friendly technology, difference is not predictable. Therefore we enlarge pollution of environment friendly technology:



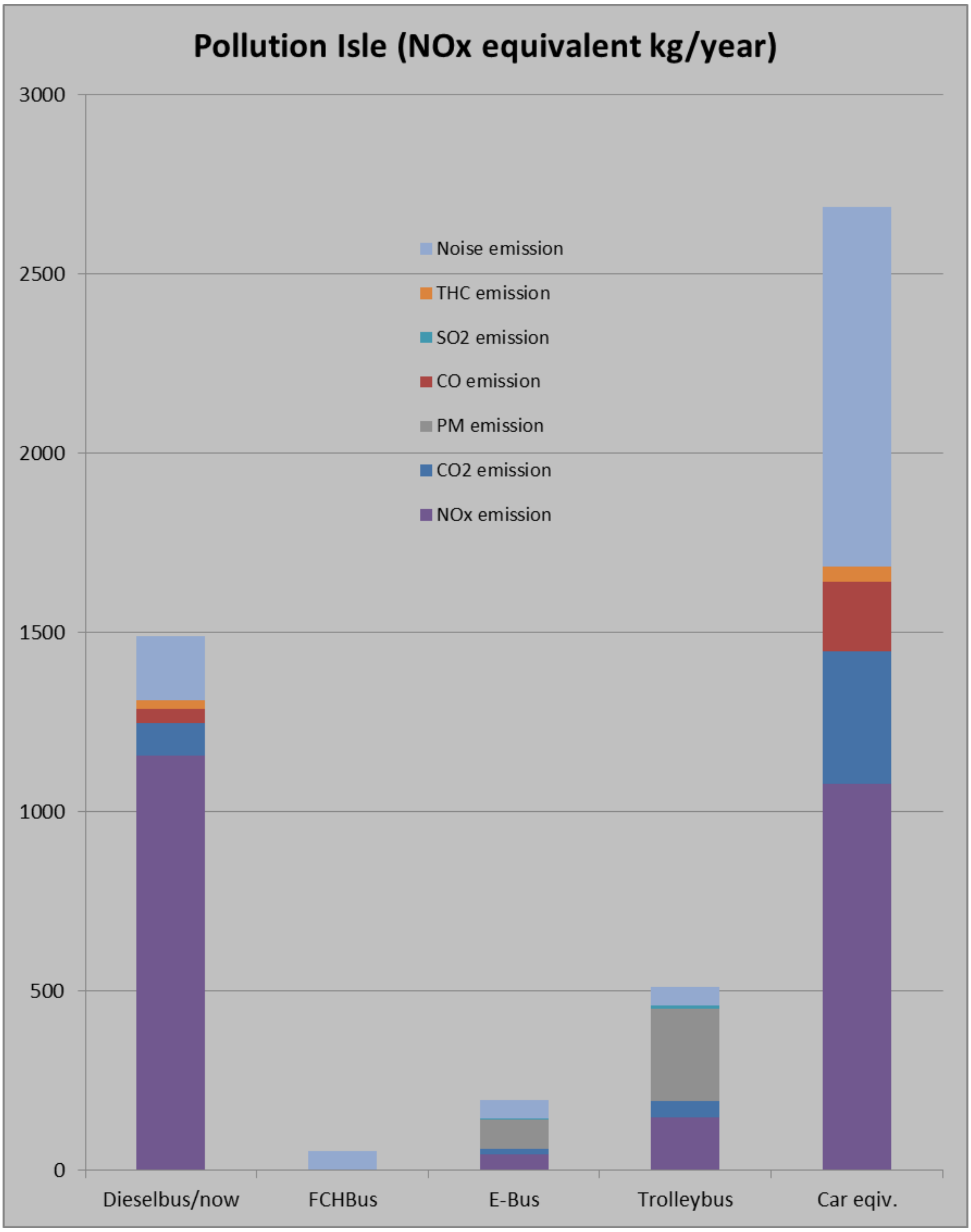
There distinctly visible, old trolleybus technology has higher global pollution. Its reason is a higher consumption and loss.

Remarkable, trolleybus, Ebus and FCHbus more environment friendly than combustion engine technology, because last one spread its pollution at streets (e.g. narrow street), firsts spread it around power plants in a controlled way. Therefore, one of most important advantage trolleybus, Ebus and FCHbus technology not show in diagram above. To show that we draw pollution of all technology which spread in Isle and in city centre:



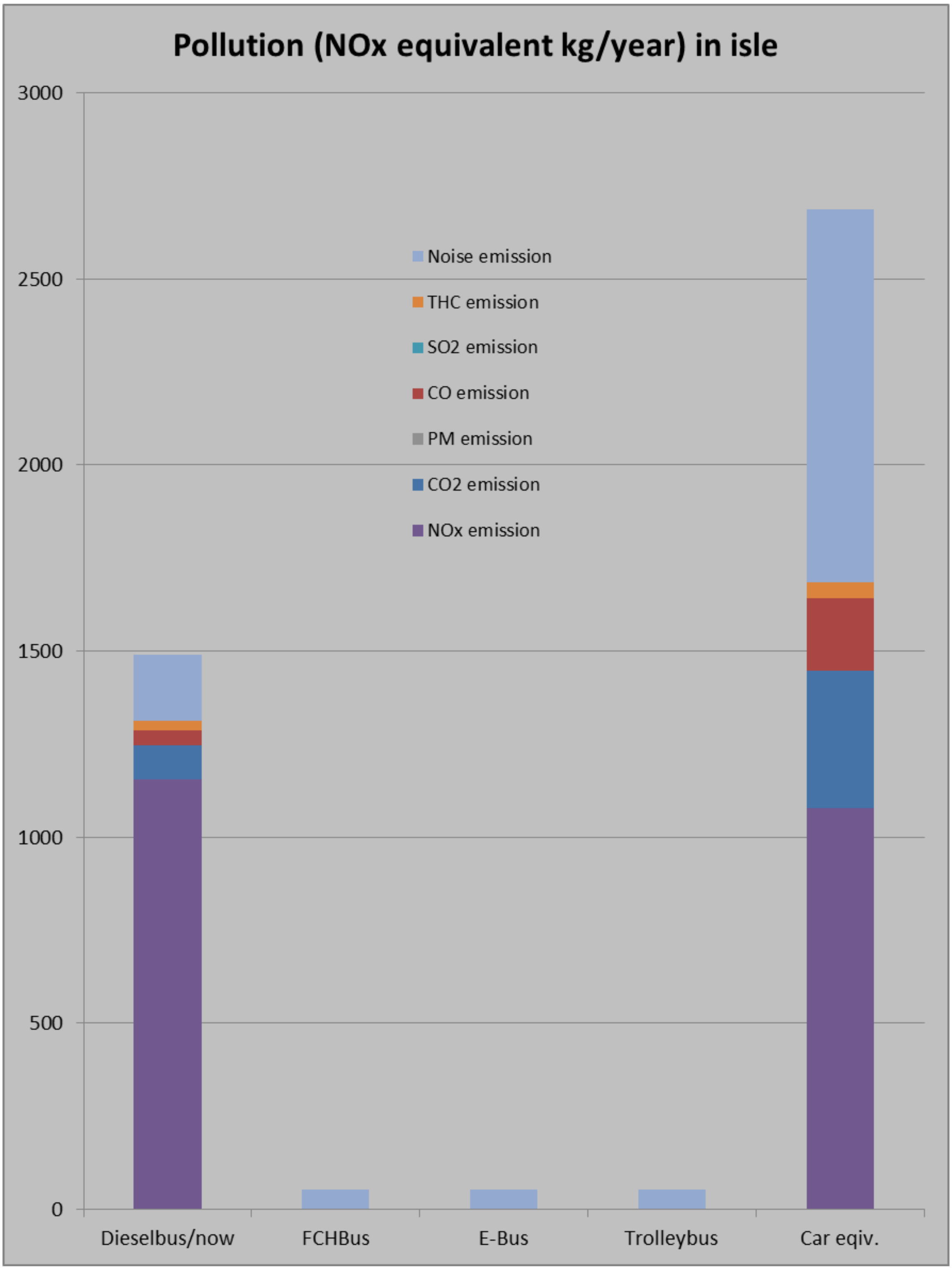
There we show advantage of three environment friendly solution. Globally spread significantly less pollution, but in Isle and in city centre spread only noise. Therefore, diesel solution spread ~15000kg NOx equivalent pollution, three environment friendly solution spread ~500kg (just noise). This is a radical decreasing of environmental load at related areas.

If we limit area under survey to Isle, then characteristic is not changed significantly:



Today buses spread here near ~1500kg equivalent pollution. If everybody use a car here instead of bus, then can be increased to ~2700kg. Trolleybus equivalent pollution is ~500kg/year. Ebus to little bit lower value to ~200kg/year, which is significantly higher than FCHbus. FCHbus pollution only noise at ~50kg/year.

Remarkable, trolleybus, Ebus and FCHbus more environment friendly than combustion engine technology, because last one spread its pollution at streets (e.g. narrow street), firsts spread it around power plants in a controlled way. Therefore, one of most important advantage trolleybus, Ebus and FCHbus technology not show in diagram above. To show that we draw pollution of all technology which spread in isle:



There we show advantage of three environment friendly solution. Globally spread significantly less pollution, but in Isle and in city centre spread only noise. Therefore, diesel solution spread ~1500kg NOx equivalent pollution, three environment friendly solution spread ~50kg (just noise). This is a radical decreasing of environmental load at related areas.

Remarkable, there is no practical experience about Ebusz technology. Therefore results based on technical specification of manufacturers and based on technology related calculation!

Secondary

Ration of Hungarian supplier can be high for Ebus and FCHbus technology, if be success to bring high quality production into honour. This can be initiative of environment friendly public transport vehicle designing and production for Europe. This can be base for producing environment friendly vehicles. This above can be result more workplace and more internal revenue.

Secondary environmental

Telling the truth, state by BKV's raunchy buses demonstrate how unimportant protection of environment and health. Unfortunately, Hungarian people is amendable to follow state's guiding.

If exceptionally environment friendly buses appear in a capitol city, make people think about own environment culture.

Make people think about why bus filled with people environment friendly than its own car. If think about, then may understand why good if buy EUROII car instead EUROII, or why good if buy EUROV car instead EUROIII. If just half of auto-owners do in that that way, then result 9MrdHUF sum of many related to health costs (and decreasing pollution) in capitol city. However, this equal all budget of that project.

If just half of driver change to public transport, then result 6MrdHUF sum of many related to health costs (and decreasing pollution). However, this more than half of that project's budget.

Generally

For example iconic result of that project is, pollution significantly decreasing, operating costs decreasing, service frequency and transport capacity doubled.

Duration

First we wish to make clear object of that project is not to changing duration. Project's object is to provide up-to-date vehicles which has significantly lower pollution and cultured environment for passengers. Of course requirement the same or less operating cost.

Route 15 Radnóti Miklós street, Csanády street and Lehel square stop omitted because redirection of. Here trolleybus and metro line accessible within 200m. In that way duration is not changing.

Other sider, redirection of route 15 give function, it can serve city centre-isle tourist axle. Furthermore service frequency at isle doubled.

If be a success to harmonize route "A" and "B", then cut in two does no generate significant changes for duration. On contrary, route "A" provide a change to metro line 3 in a way where miss 5 stop (and one chaotic intersection), therefore duration can decreased for both direction.

Cost calculation

Because its complexity details of cost calculation are published by simplified reference calculation in chapter Reference calculation. Detailed result are published in chapter Detailed calculation.

Investment and maintenance cost

For technical calculation cost which reflect circumstance of Hungary was used. If it was not available, then international cost standards near to circumstance of Hungary was used. If it was not available (e.g. cogwheel train), then estimated value was used for calculation.

Environment protection cost.

For environment protection cost calculation international (EU and developed countries) calculation method and value was used. If it was not available (e.g. noise kilogram cost), then known calculation method was extended for calculation. If it was not available (e.g. short-term air pollution exposure), then we elaborate own calculation method based on scientific achievements.

Pollution's health cost defined in international standards in EUR/km base. Where comparison of different pollutant was necessary, then we converted to NOx common denominator by its cost. Ratio calculated by health cost (for noise too!).

Remarkable, during our calculation health damage cost was underestimated. First reason is, vehicles of BKV amortized to such an extent that there is no any kind of measuring data for today's old buses. Therefore our calculations based on healthy vehicle's date.

Other side, calculations method are related to average city environment. There is no reference data and calculation for environment load sensible narrow streets. Therefore, our calculation result less health damage cost than real. Unfortunately situation are same for Isle, where number of people seek repose are high.

Final conclusion

By that project two environment friendly bus can put into operation for cost of one traditional diesel. That verify by solution of that project and by calculation of developed countries. Calculation include system build cost. Besides operating cost of environment friendly technology not exceed (sometimes less) than cost of traditional technology. As achievement, pollution and as result health and supplementary cost significantly decreased.

Robust trolleybus technology or new EBus or hydrogen fuel cell (FCH) bus technology can be applied.

Result of analysis is, using FCHBus technology is much as environment friendly, can be extendable, its component can used for other purposes. At exceptional situation and disaster can provide service. Its disadvantage is to require high level of maintenance. Using narrow street within high buildings can be problematic. In other parts of the world based on viewpoint of transport and economic easy to decide EBus – FCHBus dilemma. To decide in Hungary over in profession, other words task of government.

EBus is economical by result, but there no practical experience for city bus usage. Its environment load higher than FCHbus technology, commensurable to trolleybus technology. Its capital cost is a most inexpensive. To applying require courage because its power, driving range, transport capacity limit and may does not go smoothly.

Trolleybus technology is always alternative like every time. Its disadvantage is a little bit higher environment load and its tied path.

Ration of Hungarian supplier can be high for trolleybus technology. Ration of Hungarian supplier can be high for EBus and FCHBus technology, if be success to bring high quality production into honour. This can be initiative of environment friendly public transport vehicle designing and production for Europe. This can be base for production environment friendly vehicles. This above can be result more workplace and more internal revenue.

If we replace a vehicle fleet in a way where we change to environment friendly technology, then we can buy two especially environment friendly bus for cost of one traditional bus.

To sum it up, all analysis make unambiguous, changing form traditional technology based public transport to especially environment friendly one using cohesion founds is effective, environment friendly and accessible solution.

Copyright

Subject owners and editors

Subject owners

Forum: -

Name: -

E-mail: -

Editor

Zsolt Kendi (ÁK52 main organizer)

Tel: +36 20 2010647

E-mail: kzsolt@datanet.hu, ak52@fw.hu

Acknowledgment

In that way we would like to say thank to specialists for its assistance, who help us to found out best solution using its own free time, and not ashamed to wed out our fail conceptions.

We had no choice to speak many subject without help of excellent specialists. Therefore, our most important task is to say thank you for that help to each of them. If it was possible, we show name in a

related document. If requested to hide that name, then a best way to say thank you go far to respect it.

Made by

in ÁK52 private organization.

Budapest, 10.2012 – 03.2013

Appendix 1.

References

Traditional technology

Bus

http://virtual.vtt.fi/virtual/amf/pdf/annex17_paper_2001_sae.pdf

Influence of Vehicle Test Cycle Characteristics on Fuel Consumption and Emissions of City Buses, Luc Pelkmans, Dirk De Keukeleere, Hans Bruneel and Guido Lenaers Vito, Flemish Institute for Technological Research

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.201.5043&rep=rep1&type=pdf

Emissions and fuel consumption of natural gas powered city buses versus diesel buses in real-city traffic, L. Pelkmans, D. De Keukeleere & G. Lenaers Vito . Flemish Institute for Technological Research, Belgium

http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=538197&fileOId=625774

Lean Burn Natural Gas Operation vs. Stoichiometric Operation with EGR and a Three Way Catalyst Patrik Einewall, Per Tunestål and Bengt Johansson Lund Institute of Technology

http://www.eltis.org/docs/studies/Betrieb_mit_Fluessiggas.pdf

Öffentlicher Verkehr in Wien Flüssiggasbetrieb bei den Wiener Linien

Trolleybus

http://www.trolleymotion.ch/fileadmin/user_upload/documents/salzburg_obus_positionspapier_EU.pdf

Positionspapier Trolleybus, Betreffend die EU-Verordnung zur Vergabe öffentlicher Dienstleistungsauftrage im Personenverkehr. Marz 2004 Salzburg/Austria Konferenz.

http://www.tbus.org.uk

the Electric tbus group

http://www.tbus.org.uk/vtpn3.pdf

The Benefits of Clean, Quiet, Emission-Free Transit Service: Promoting the Trolleybus in Vancouver , Written by Kevin Brown The TBus Group

http://www.kuma.ch/EN/Railways-Catenary-engineering/Tram-Trolleybus/Pages/default.aspx

Kummler+Matter Tram-trolley development

http://www.vossloh-kiepe.com/electric-buses

Vossloh-kiepe Electric buses development

http://www.edmonton.ca/transportation/transit/Checkel_ExecutiveSummary.pdf

Hybrid Diesel-Electric Bus / Trolley Bus Demonstration Project: Technical Comparison of In-Use Performance Dr. David Checkel Mechanical Engineering University of Alberta April 18, 2008

http://www.edmonton.ca/transportation/transit/App_G_LifeCycleEmissionMethods.pdf

HYBRID DIESEL-ELECTRIC BUS / TROLLEY BUS DEMONSTRATION PROJECT: TECHNICAL COMPARISON OF IN-USE PERFORMANCE APPENDIX G LIFE CYCLE EMISSION METHODS AND DETAILS, Hybrid Diesel- Trolley Bus Demonstration Project

http://metro.kingcounty.gov/up/projects/pdf/TrolleyEvaluation_PreliminaryFindings_Apr2011.pdf

King Country Metro, Trolley Bus System Evaluation

Tram (light rail)

http://www.hamilton.ca/NR/rdonlyres/A5E6E5F1-C6AD-4745-A733-166A3EDF079F/0/TechnologyAnalysis.pdf

Light Rail Technology Overview and Analysis

http://www.modernstreetcar.org/pdf/circulator_trackway_report_final_3_30_07.pdf

Trackway Infrastructure Guidelines for Light Rail Circulator Systems

http://www.toronto.ca/involved/projects/kingstonrd/pdf/2013-05-27-boards-4.pdf

Resilient Embedded Track (RETRAC) technology

http://www.zpsv.cz/ohl-group/katalogy/ZPSV-katalog2013-lowres.pdf

http://www.zpsv.cz/Produkt.aspx?lang=en&cat=KZ&sku=zel-stavby&skup=kolejnicove-podpory-zeleznicnich-a-tramvajovych-koleji&prod=tramvajovy-panel-dzp-220194-p

ZPSV product catalogue (tram panel)

FCH technology

http://www.fuelcells.org/wp-content/uploads/2012/02/fcbuses-world.pdf

fuelcell.org, Fuel Cell Buses - Worldwide

http://www.fch-ju.eu/

Fuel cells and hydrogen joint undertaking

http://www.nrel.gov/hydrogen/publications.html

US National Renewable Energy Laboratory: Publications

http://www.greencarcongress.com/2006/03/european_fuelce.html

Green Car Congress, European Fuel-Cell Bus Projects Extended by One Year

http://www.buchmann.ca/Article1-page1.asp

Isidor Buchmann, The Fuel Cell: is it ready?

http://www.crest-au.com/docs/alt_CBA.pdf

MURDOCH UNIVERSITY, A Cost-Benefit Analysis of Perth's Hydrogen Fuel Cell Buses

http://www.rita.dot.gov/publications/fuel_cell_bus_life_cycle_cost_model/pdf/entire.pdf

US Department for Transport: Fuel Cell Bus Life Cycle Cost Model: Base Case & Future Scenario Analysis, Entire Report

http://www.ieafuelcell.com/documents/Fuel_Cells_for_Buses_Jan_2012.pdf Fuel Cell Transit Buses R. Ahluwalia, X. Wang, and R. Kumar Argonne National Laboratory, Argonne, IL January 31, 2012

http://www.global-hydrogen-bus-platform.com/

HyFLEET:CUTE project

http://www.hydrogen-motors.com/man.html

Hydrogen motors: MAN Lion's City (2006)

http://www.hydrogen-motors.com/mercedes-benz-citaro-fuel-cell.html

Hydrogen motors: Mercedes-Benz Citaro Fuel Cell (2006)

http://www.bus-bild.de/name/galerie/kategorie/alternative-antriebe~wasserstoff-brennstoffzelle~mercedes-benz-o-530-bz-citaro-fuel-cell.html

bus-bild.de: Mercedes-Benz O 530 BZ (Citaro Fuel Cell)

http://www.bus-bild.de/name/galerie/kategorie/alternative-antriebe~wasserstoff-brennstoffzelle~man-niederflurbus-3-generation-lions-city-h2-mit-brennstoffzelle.html

bus-bild.de: MAN Niederflurbus 3. Generation (Lion's City H2 mit Brennstoffzelle)

http://www.fuelcellseminar.com/media/5277/dem43-3_scott.pdf

ISE: Implementation of Fuel Cell Transit Bus Service for Canada and London

http://nexthylights.eu/Publications/Clean-3_D3-1_WP3_EE_State_of_the_Art_23rd-FEB-2011.pdf

R. Zaetta, B. Madden (Element Energy): Hydrogen Fuel Cell Bus Technology State of the Art Review

http://www.vossloh-kiepe.com/electric-buses/hybrid-buses/h2-hybrid-bus

Vossloh Kiepe: H2 hybrid bus Phileas

http://www.ballard.com/fuel-cell-applications/bus.aspx

Ballard: Fuel cell applications

http://www.ika.rwth-aachen.de/r2h/index.php/Hydrogen_and_Fuel_Cell_Technology

KA RWTH Aachen University: Hydrogen and Fuel Cell Technology

http://www.fuelcells.org/wp-content/uploads/2012/02/busreport.pdf

US Federal Transport Association, National Fuel Cell Bus Program: A Report on Worldwide Hydrogen Bus Demonstrations, 2002-2007

http://www.hydrogen.energy.gov/pdfs/12012_fuel_cell_bus_targets.pdf

US Department of Energy: Fuel Cell Technologies Program Record

http://www.actransit.org/wp-content/uploads/NREL_rept_OCT2010.pdf

NREL: Fuel Cell Buses in U.S. Transit Fleets: Current Status 2010

http://www.nrel.gov/hydrogen/pdfs/54860.pdf

NREL: National Fuel Cell Electric Vehicle Learning Demonstration Final Report

FCHBus operators

http://chic-project.eu/

Clean Hydrogen In European Cities project home

http://busride.com/2009/05/ac-transit-grows-to-12-hyroad-zero-emission-vehicles/

Busride: AC Transit grows to 12 HyRoad zero-emission vehicles

http://www.fuelcellmarkets.com/fuel_cell_power/news_and_information/3,1,6250,1,28987.html

fuelcellmarkets.com, Fuel cell buses EU and UK

http://en.gvb.nl/overgvb/brandstofcelbus/Pages/default.aspx

GVB: Fuel cell bus

http://en.gvb.nl/overgvb/brandstofcelbus/Pages/Onderdelen-bus.aspx

GVB: Fuel cell bus, implemented components explored!

http://highvlocity.eu/

High V.LO-City project

http://www.hymove.nl/en/home/

Province project HyMove

http://www.actransit.org/environment/the-hyroad/

AC transit: HyRoad

http://www.nrel.gov/hydrogen/proj_fc_bus_eval.html

NREL: Hydrogen Fuel Cell Bus Evaluations

http://www.nrel.gov/hydrogen/pdfs/55367.pdf

NREL: Zero Emission Bay Area (ZEBA) Fuel Cell Bus Demonstration: Second Results Report

H2 parts

http://www.dynetek.com/hydrogen.php

Dynetek Industries Ltd.: Hydrogen products

http://www.ballard.com/fuel-cell-products/

Ballard: Fuel cell products

http://www.ballard.com/files/PDF/Media/IWG_Final.pdf

Ballard: Putting Fuel Cells to Work

http://www.utcpower.com/products/transportation/fleet-vehicles

UTC power: Transportation Fleet Vehicles

http://www.iea.org/publications/freepublications/publication/hydrogen.pdf

INTERNATIONAL ENERGY AGENCY, INTERNATIONAL ENERGY AGENCY, HYDROGEN PRODUCTION

AND STORAGE

http://www.princeton.edu/pei/energy/publications/reports/No.318.pdf

Joan M. Odgen: Prospects for Building a hydrogen energy infrastructure

http://www.hydrogenics.com/assets/pdfs/Fueling%20Station_English.pdf

Hydrogenics: Electrolysis-based Fueling stations

http://www.fuelcellseminar.com/media/9138/com43-2%20yang.pdf

Austin Power Engineering, Yang Young: Cost Analysis of Direct Hydrogen PEM Fuel Cell/Lithium Ion Battery Hybrid Power Source for Transportation

http://www1.eere.energy.gov/hydrogenandfuelcells/tech_validation/pdfs/fcm07r0.pdf

College of the Desert: Fuel Cell Bus Maintenance

http://www.ecn.nl/docs/library/report/2009/l09177.pdf

ECN: PEM Fuel Cells Durability and Cost

http://xa.yimg.com/kq/groups/3004572/636040941/name/A%20review%20of%20PEM%20fuel%20cell%20durability.pdf

Journal of Power Sources: A review of PEM fuel cell durability: Degradation mechanisms and mitigation strategies

http://www.dynetek.com/hydrogen.php#2

Dynetek: Hydrogen products

H2 production

http://www.hydrogen.energy.gov/h2a_prod_studies.html

Current_Central_Electrolysis_version_3_02062012Current_Central_Electrolysis_version_3_02062012.xls input: Capital Costs „Number of Electrolyser units in the plant"

Todd Ramsden & Mark Ruth: Current (2010) Hydrogen Production from Central Grid Electrolysis

http://www.hydrogen.energy.gov/pdfs/review04/hpd_16_cohen.pdf

Teledyne: Hydrogen Generation from Electrolysis By Steve Cohen & Samir Ibrahim

http://www.electrochemsci.org/papers/vol7/7043314.pdf

International Journal of ELECTROCHEMICAL SCIENCE: Electrical Efficiency of Electrolytic Hydrogen Production

http://www.nrel.gov/hydrogen/pdfs/36734.pdf

National Renewable Energy Laboratory: Summary of Electrolytic Hydrogen Production

http://www.alternative-energy-news.info/technology/hydrogen-fuel/

Alternative energy: Hydrogen fuel

http://www.crest-au.com/docs/H2ProductionfromRenewablesbyElectrolysis%20_Mar%202010v5.pdf

Centre for Research into Energy for Sustainable Transport: Hydrogen Production from Renewable Energy by Electrolysis

H2 storage

http://www.madrimasd.org/queesmadrimasd/Pricit/PlanNet/documentos/03/documentos/publico/TDAUF/Hidrogeno/storage_1998.pdf

National Renewable Energy Laboratory: Costs of Storing and Transporting Hydrogen

http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/27079.pdf

National Renewable Energy Laboratory: Survey of the Economics of Hydrogen Technologies

http://www.cleanenergystates.org/assets/2011-Files/Hydrogen-and-Fuel-Cells/CESA-Lipman-H2-prod-storage-050311.pdf

Timothy Lipman: An Overview of Hydrogen Production and Storage Systems with Renewable Hydrogen Case Studies

http://repositories.lib.utexas.edu/handle/2152/ETD-UT-2010-12-2231

Tobin Micah Powell: Design of an Underground Compressed Hydrogen Gas Storage Facility for Use at Fuelling Stations

http://www.ika.rwth-aachen.de/r2h/index.php/Underground_Hydrogen_Storage_in_Refuelling_Stations

IKA RWTH Aachen University: Underground Hydrogen Storage in Refuelling Stations

http://www.ika.rwth-aachen.de/r2h/index.php/Large_Hydrogen_Underground_Storage

Large Hydrogen Underground Storage

http://www.fuelcellseminar.com/media/9228/a16_1.pdf

Dr. Susan Schoenung: Benefit/Cost Analysis of Large-Scale Hydrogen Storage for Renewable Utility Applications

http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/ihfpv_zheng2.pdf

Zhejiang university: R&D of Large Stationary Hydrogen/CNG/HCNG Storage Vessels

H2 safety

http://hysafe.org/home

HySafe - Safety of Hydrogen as an Energy Carrier

http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/cng_h2_workshop_8_wong.pdf

Powertech Labs Inc.: CNG & Hydrogen Tank Safety, R&D, and Testing

http://www.40fires.org/Wiki.jsp?page=Hydrogen%20Safety

40 fires foundation: Hydrogen Safety

http://avogadro.chem.iastate.edu/MSDS/hydrogen.pdf

Air Products: MATERIAL SAFETY DATA SHEET, Hydrogen, compressed

http://www.hysafe.org/science/eAcademy/docs/1stesshs/presentations/Ireland_hydrogen_safety.pdf

LeeMcGill University, Montreal, Canada, Professor John H.S. Lee, Professor John H.S. Lee

http://www.lbst.de/download/2012/DWV_Hydrogen-Safety-Compendium_WHEC2012_07JUN2012.pdf

Ludwig Bölkow Systemtechnik GmbH (LBST): DWV Hydrogen Safety Compendium

http://www.ineris.fr/centredoc/risoe_final.pdf

INERIS: New energy, new hazards? The hydrogen scenario.

H2 refuelling

http://www.hi-energy.org.uk/Downloads/Hydrogen%20Fuel%20Cell%20Resource/3b-Hydrogen%20refuelling%20and%20storage%20infrastructure.pdf

Hydrogen Refuelling & Storage Infrastructure: Hydrogen Refuelling & Storage Infrastructure

http://its.ucdavis.edu/

Jonathan X. Weinert Institute of Transportation Studies - UC Davis: A Cost Analysis of Hydrogen

Stations for the California

http://its.ucdavis.edu/

Jonathan X. Weinert Institute of Transportation Studies - UC Davis: A Near-Term Economic Analysis of Hydrogen Fuelling Stations

Power plant

http://www.world-nuclear.org/info/inf11.html

World Nuclear Association: Energy Analysis of Power Systems

http://cec.org/Storage/130/15530_power_plants_english_web.pdf

Commission for Environmental Cooperation: North American Power Plant Air Emissions

H2 power plant

http://your.kingcounty.gov/dnrp/library/wastewater/energy/FuelCell/0803FuelCellDemoProjectSummary.pdf

Fuel Cell Energy: King County Fuel Cell Demonstration

Environment impact

http://h2g2.com/approved_entry/A16407173

h2g2, Atmospheric Pollution from the Internal Combustion Engine in the Urban Environment

http://people.hofstra.edu/geotrans/eng/ch8en/conc8en/ch8c1en.html

THE GEOGRAPHY OF TRANSPORT SYSTEMS, The Environmental Impacts of Transportation

http://delphi.com/pdf/emissions/Delphi-Passenger-Car-Light-Duty-Truck-Emissions-Brochure-2011-2012.pdf

Delphi, Worldwide Emission Standards Passenger Cars and Light Duty Vehicles

http://www.energy.eu/publications/Analyzing-on-road-emissions-of-light-duty-vehicles-PEMS.pdf

JRC, Analysing on-road emissions of light-duty vehicles with PEMS

http://www.eea.europa.eu/publications/transport-and-air-quality-term-2012/at_download/file

EEA Report No 10/2012, The contribution of transport to air quality TERM 2012: transport indicators tracking progress towards environmental targets in Europe

http://www.eea.europa.eu/publications/air-quality-in-europe-2012/at_download/file

EEA Report No 4/2012 Air quality in Europe — 2012 report

http://ec.europa.eu/environment/archives/cafe/activities/pdf/cafe_cba_externalities.pdf

AEA Technology Environment, Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme

http://www.crest-au.com/docs/alt_CBA.pdf

MURDOCH UNIVERSITY, A Cost-Benefit Analysis of Perth's Hydrogen Fuel Cell Buses http://www.epa.gov/otaq//models/nonrdmdl/nonrdmdl2010/420r10015.pdf

US Environmental Protection Agency, Conversion Factors for Hydrocarbon Emission Components

http://www.dfld.de/Downloads/EU_080115_HandbuchExterneKostenVerkehr.pdf

CE Delft, Handbook on estimation of external cost in the transport sector

http://www.unc.edu/~shashi/AirQuality/outdoorair.html

UNC CEP Amber Hamm: Outdoor Air Quality

http://www.epa.gov/airquality/carbonmonoxide/index.html

US Environmental Protection Agency: Carbon Monoxide

http://www.carbonmonoxidekills.com/59/carbon_monoxide_motor_vehicles

Carbon Monoxide: Carbon Monoxide and Motor Vehicles

http://archive.defra.gov.uk/environment/quality/air/airquality/panels/igcb/documents/dcs-report2006.pdf

AEA Technology, ED48796. Damage Costs for Air Pollution

http://www.vtpi.org/tca/tca0510.pdf

Victoria Transport Policy Institute: Transportation Cost and Benefit Analysis II – Air Pollution Costs

http://www.euro.who.int/__data/assets/pdf_file/0006/74715/E86650.pdf

World Health Organization Europe, Health effects of transport-related air pollution

http://aida.econ.yale.edu/~nordhaus/Resources/Muller_overview.pdf

Nicholas Z. Muller & Robert Mendelsohn: Measuring the Damages of Air Pollution in the United States

http://www.toronto.ca/health/hphe/pdf/air_pollution_burden.pdf

Toronto Public Health, Dr. David McKeown, Air Pollution Burden of Illness from Traffic in Toronto

http://jama.jamanetwork.com/article.aspx?articleid=1104975#qundefined

JAMA The Journal of the American Medical Association: Main Air Pollutants and Myocardial Infarction A Systematic Review and Meta-analysis

http://www.vti.se/en/publications/pdf/tyreroad-noise--myths-and-realities.pdf

Tyre/road noise – Myths and realities, Ulf Sandberg, Plenary paper published in the Proceedings of The 2001 International Congress and Exhibition on Noise Control Engineering, The Hague, The Netherlands, 2001 August 27–30

* * *

Appendix 2.

Calculation base data

In that appendix shown base data by route which used for calculation:

15 (original)

Calculation inputs:

Follow time average	min	10
Follow time minimal	min	10
Route length	km	4,6
Duration max	min	35
Operating time	hour	14
Operating days in a year	n	257
Vehicle spare ratio	%	130
Average number of passengers vehicle	n	34
Average number of passengers car	n	1,2

26 (original)

Calculation inputs:

Follow time average	min	20
Follow time minimal	min	15
Route length	km	4,5
Duration max	min	20
Operating time	hour	16
Operating days in a year	n	360
Vehicle spare ratio	%	130
Average number of passengers vehicle	n	34
Average number of passengers car	n	1,2

Isle (virtual)

Calculation inputs:

Follow time average	min	20
Follow time minimal	min	15
Route length	km	2,2

Duration max	min	10
Operating time	hour	16
Operating days in a year	n	360
Vehicle spare ratio	%	130
Average number of passengers vehicle	n	34
Average number of passengers car	n	1,2

15

Calculation inputs:

Follow time average	min	10
Follow time minimal	min	10
Route length	km	8,1
Duration max	min	46
Operating time	hour	14
Operating days in a year	n	257
Vehicle spare ratio	%	130
Average number of passengers vehicle	n	34
Average number of passengers car	n	1,2

Overhead wire for Boráros square to Szent István boulevard:

Will need to build network anchor type	km	3,96
Will need to build network pole type	km	0,14
Will need to build network column type	km	0,00
Will need to build network column + pole type	km	0,38

26A

Calculation inputs:

Follow time average	min	20
Follow time minimal	min	15
Route length	km	4,8
Duration max	min	22
Operating time	hour	3
Operating days in a year	n	360
Vehicle spare ratio	%	130
Average number of passengers vehicle	n	34
Average number of passengers car	n	1,2

Overhead wire from Árpád bridge to Szent István boulevard:

Will need to build network anchor type	km	3,90
Will need to build network pole type	km	0,00
Will need to build network column type	km	0,65
Will need to build network column + pole type	km	0,00

99 (original)

Calculation inputs:

Follow time average	min	10
Follow time minimal	min	6
Route length	km	11,6
Duration max	min	50
Operating time	hour	18
Operating days in a year	n	360
Vehicle spare ratio	%	130
Average number of passengers vehicle	n	56
Average number of passengers car	n	1,2

99A

Calculation inputs:

Follow time average	min	10
Follow time minimal	min	6
Route length	km	5,2
Duration max	min	25
Operating time	hour	18
Operating days in a year	n	360
Vehicle spare ratio	%	130
Average number of passengers vehicle	n	56
Average number of passengers car	n	1,2

Overhead wire:

Will need to build network anchor type	km	5,23
Will need to build network pole type	km	0,13
Will need to build network column type	km	0,20
Will need to build network column + pole type	km	0,00

99B

Calculation inputs:

Follow time average	min	10
Follow time minimal	min	6
Route length	km	6,4
Duration max	min	25
Operating time	hour	18
Operating days in a year	n	360
Vehicle spare ratio	%	130
Average number of passengers vehicle	n	56
Average number of passengers car	n	1,2

One car

We suppose, one car do in a city one there and back every workday.

Calculation inputs:

Follow time average	min	60
Follow time minimal	min	60
Route length	km	10
Duration max	min	10
Operating time	hour	1
Operating days in a year	n	257
Vehicle spare ratio	%	130
Average number of passengers vehicle	n	34
Average number of passengers car	n	1,2
Average number of passengers cogwheel train	n	83

With EUROIII engine:

Diesel CO2 emission vehicle	kg/km	0,23000
Diesel CO emission vehicle	kg/km	0,00060
Diesel THC emission vehicle	kg/km	0,00010
Diesel NOx emission vehicle	kg/km	0,00050

With EUROV engine:

Diesel CO2 emission vehicle	kg/km	0,23000
Diesel CO emission vehicle	kg/km	0,00047

Diesel THC emission vehicle	kg/km	0,00004
Diesel NOx emission vehicle	kg/km	0,00018

* * *

Appendix 3.

Detailed calculation

Following pages shown result of detailed calculations.

Investment common

Investment common	item	unit	unit price HUF	total price HUF
Isle				
Paving	2,1	km	30 000 000,00	63 000 000,00
Public lighting	84	piece	800 000,00	67 200 000,00
Car park cover	15500	m2	100 000,00	1 550 000 000,00
Car park grassing	15500	m2	5 400,00	83 700 000,00
Air extractor system	1	piece	53 000 000,00	53 000 000,00
Bridge Árpád				
Transparent noise wall	500	m	45 000,00	22 500 000,00
Tram track exit for bus	1	piece	3 000 000,00	3 000 000,00
Tram protect type traffic light for exit	1	piece	6 000 000,00	6 000 000,00
Rebuild stop Népfürdő street	1	piece	14 000 000,00	14 000 000,00
Bridge Margit				
Tram track exit for bus	2	piece	3 000 000,00	6 000 000,00

Tram protect type traffic light for exit	2	piece	6 000 000,00	12 000 000,00
Rebuild stop Jászai Mari square	1	piece	14 000 000,00	14 000 000,00
Ferenciek square				
Underpass ventilation and level shift	1	piece	50 000 000,00	50 000 000,00
Rade Károly and Hazinszky Frigyes walkway				
Paving	1,2	km	30 000 000,00	36 000 000,00
Public lighting	48	piece	800 000,00	38 400 000,00
Vajda Péter street				
Paving	0,8	km	30 000 000,00	24 000 000,00
Final stop Petz Ármin walkway	1	piece	100 000 000,00	100 000 000,00
Common investment cost				2 142 800 000,00

Investment need now

Investment need now	item	unit price HUF	total price HUF
Route 15			
Vehicle	10	80 000 000,00	800 000 000,00
Route 26			
Vehicle	4	80 000 000,00	320 000 000,00
Route 99A (virtual)			
Vehicle	12	80 000 000,00	960 000 000,00

Vehicle investment cost	2 080 000 000,00
Infrastructure investment cost	0,00
Common investment cost	2 142 800 000,00
Total investment cost	4 222 800 000,00

Operation now

Operation now	item	unit price	total price
		HUF	HUF
Route 15			
Fuel cost	1	57 000 955,20	57 000 955,20
Maintenance costs	1	34 236 322,85	34 236 322,85
Driver costs	1	57 750 000,00	57 750 000,00
CO2 cost	1	1 406 155,97	1 406 155,97
Health cost	1	18 739 522,69	18 739 522,69
Route 26			
Fuel cost	1	44 634 240,00	44 634 240,00
Maintenance costs	1	26 808 537,60	26 808 537,60
Driver costs	1	36 750 000,00	36 750 000,00
CO2 cost	1	1 101 081,60	1 101 081,60
Health cost	1	14 673 865,56	14 673 865,56
Route 99A (virtual)			
Fuel cost	1	116 049 024,00	116 049 024,00
Maintenance costs	1	69 702 197,76	69 702 197,76

Driver costs	1	126 000 000,00	126 000 000,00
CO2 cost	1	2 862 812,16	2 862 812,16
Health cost	1	38 152 050,46	38 152 050,46

Cost year	
Fuel cost	217 684 219,20
Maintenance costs	130 747 058,21
Driver costs	220 500 000,00
Total health cost	76 935 488,44
Cost total	645 866 765,85

Investment FCH

Investment FCH	item	unit price HUF	total price HUF
Route 15			
Vehicle	13	330 000 000,00	4 290 000 000,00
Route 99A			
Vehicle	12	330 000 000,00	3 960 000 000,00
H2 production, storage, refuelling			
H2 factory (electrolysis, 2t/day), 6t storage, refuelling station	1	1 455 465 620,00	1 455 465 620,00
Garage			
FCH bus garage build in	1	120 000 000,00	120 000 000,00

Vehicle investment cost	8 250 000 000,00
Infrastructure investment cost	1 575 465 620,00
Common investment cost	2 142 800 000,00
Total investment cost	11 968 265 620,00

Operation FCH

Operation FCH	item	unit price HUF	total price HUF
Route 15			
Fuel cost	1	31 661 637,80	31 661 637,80
Maintenance costs	1	105 499 973,12	105 499 973,12
Driver costs	1	78 750 000,00	78 750 000,00
CO2 cost	1	0,00	0,00
Health cost	1	1 252 245,94	1 252 245,94
Route 26A			
Fuel cost	1	2 815 932,21	2 815 932,21
Maintenance costs	1	9 382 988,16	9 382 988,16
Driver costs	1	15 750 000,00	15 750 000,00
CO2 cost	1	0,00	0,00
Health cost	1	111 372,62	111 372,62
Route 99A			
Fuel cost	1	36 607 118,75	36 607 118,75
Maintenance costs	1	121 978 846,08	121 978 846,08
Driver costs	1	126 000 000,00	126 000 000,00
CO2 cost	1	0,00	0,00

Health cost	1	1 447 844,11	1 447 844,11

Cost year	
Fuel cost	71 084 688,76
Maintenance costs	236 861 807,36
Driver costs	220 500 000,00
Total health cost	2 811 462,67
Cost total	531 257 958,79

Investment E-Bus

Investment E-Bus	item	unit price HUF	total price HUF
Route 15			
Vehicle	14	176 000 000,00	2 464 000 000,00
Route 99A			
Vehicle	12	176 000 000,00	2 112 000 000,00
Garage			
E-bus garage build in	1	54 000 000,00	54 000 000,00
Népliget M final stop			
Fuelling station vandal resistant	1	200 000,00	200 000,00
Boráros square final stop			
Fuelling station vandal resistant	1	200 000,00	200 000,00

Vehicle investment cost	4 576 000 000,00
Infrastructure investment cost	54 400 000,00
Common investment cost	2 142 800 000,00
Total investment cost	6 773 200 000,00

Operation E-Bus

Operation E-Bus	item	unit price HUF	total price HUF
Route 15			
Fuel cost	1	7 191 937,74	7 191 937,74
Maintenance costs	1	89 180 028,00	89 180 028,00
Driver costs	1	78 750 000,00	78 750 000,00
CO2 cost	1	404 356,12	404 356,12
Health cost	1	4 306 954,17	4 306 954,17
Route 26A			
Fuel cost	1	639 638,71	639 638,71
Maintenance costs	1	7 931 520,00	7 931 520,00
Driver costs	1	15 750 000,00	15 750 000,00
CO2 cost	1	35 962,75	35 962,75
Health cost	1	383 053,18	383 053,18
Route 99A			
Fuel cost	1	8 315 303,23	8 315 303,23
Maintenance costs	1	103 109 760,00	103 109 760,00
Driver costs	1	126 000 000,00	126 000 000,00
CO2 cost	1	467 515,70	467 515,70

Health cost	1	4 979 691,31	4 979 691,31

Cost year	
Fuel cost	16 146 879,68
Maintenance costs	200 221 308,00
Driver costs	220 500 000,00
Total health cost	10 577 533,22
Cost total	447 445 720,90

Investment trolleybus

Investment trolleybus	item	unit price HUF	total price HUF
Route 15			
Vehicle	13	150 000 000,00	1 950 000 000,00
Overhead wire build	1	673 016 000,00	673 016 000,00
Ferenciek square underpass heighten	1	120 000 000,00	120 000 000,00
Ferenciek square underpass replacing public-utility	1	43 000 000,00	43 000 000,00
Route 26A			
Overhead wire build	1	711 100 000,00	711 100 000,00
Route 99A			
Vehicle	12	150 000 000,00	1 800 000 000,00
Overhead wire build	1	801 100 000,00	801 100 000,00

Vehicle investment cost	3 750 000 000,00
Infrastructure investment cost	2 348 216 000,00
Common investment cost	2 142 800 000,00
Total investment cost	8 241 016 000,00

Operation trolleybus

Operation trolleybus	item	unit price HUF	total price HUF
Route 15			
Fuel cost	1	22 853 868,51	22 853 868,51
Maintenance costs	1	117 479 823,55	117 479 823,55
Driver costs	1	78 750 000,00	78 750 000,00
CO2 cost	1	1 284 925,15	1 284 925,15
Health cost	1	10 959 212,87	10 959 212,87
Route 26A			
Fuel cost	1	2 032 584,19	2 032 584,19
Maintenance costs	1	10 448 455,68	10 448 455,68
Driver costs	1	15 750 000,00	15 750 000,00
CO2 cost	1	114 279,06	114 279,06
Health cost	1	974 693,75	974 693,75
Route 99A			
Fuel cost	1	26 423 594,50	26 423 594,50
Maintenance costs	1	135 829 923,84	135 829 923,84
Driver costs	1	126 000 000,00	126 000 000,00
CO2 cost	1	1 485 627,74	1 485 627,74
Health cost	1	12 671 018,77	12 671 018,77

Cost year	
Fuel cost	51 310 047,20
Maintenance costs	263 758 203,07
Driver costs	220 500 000,00
Total health cost	27 489 757,34
Cost total	563 058 007,60

Summary help

Dieselbus/now pollution (NOx equivalent)	15ere	26ere	99A virt	all
CO2 emission	238,3315	186,624	485,2224	910,1779
CO emission	104,27	81,648	212,2848	398,2028
SO2 emission	0	0	0	0
THC emission	65,11558	50,98834	132,5696914	248,6736
PM emission	0	0	0	0
NOx emission	3018,866	2363,904	6146,1504	11528,92
Noise emission	462,5419	362,1905	941,6953728	1766,428

FCHBus pollution (NOx equivalent)	15	26A	99A	all
CO2 emission	1,57E-09	1,40E-10	1,82E-09	3,53E-09
CO emission	0	0	0	0
SO2 emission	2,50E-06	2,22E-07	2,89E-06	5,61E-06
THC emission	0	0	0	0
PM emission	1,51E-05	1,34E-06	1,75E-05	3,39E-05
NOx emission	2,10E-06	1,87E-07	2,43E-06	4,71E-06
Noise emission	243,96	21,70	282,07	547,72

E-Bus pollution (NOx equivalent)	15	26A	99A	all
CO2 emission	68,53494	6,095381	79,24	153,8703
CO emission	0	0	0	0
SO2 emission	9,061842	0,805945	10,48	20,34507
THC emission	0	0	0	0
PM emission	372,8301	33,15887	431,07	837,0542
NOx emission	213,2198	18,96341	246,52	478,7075
Noise emission	243,9598	21,69737	282,07	547,7231

Trolleybus pollution (NOx equivalent)	15	26A	99A	all
CO2 emission	217,7839	19,36933	251,8013123	488,9546
CO emission	0	0	0	0
SO2 emission	28,79587	2,561056	33,29372906	64,65066
THC emission	0	0	0	0
PM emission	1184,745	105,3692	1369,799139	2659,913
NOx emission	677,55	60,26014	783,3818604	1521,192
Noise emission	243,9598	21,69737	282,0658464	547,7231

Car equiv. pollution (NOx equivalent)	15ere	26ere	99A virt	all
CO2 emission	970,7044	760,104	3255,0336	4985,842
CO emission	506,4545	396,576	1698,2784	2601,309
SO2 emission	0	0	0	0
THC emission	108,526	84,98057	363,9168	557,4233
PM emission	0	0	0	0
NOx emission	2813,636	2203,2	9434,88	14451,72
Noise emission	2616,963	2049,196	8775,381888	13441,54

H2 consumption				
kg/day	163,3	10,37	134,78	308,45

Summary

Summary	Dieselbus/now	FCHBus	E-Bus	Trolleybus
	MHUF	MHUF	MHUF	MHUF
Investment costs				
Vehicle acquisition	2 080,00	8 250,00	4 576,00	3 750,00
Establishing infrastructure	0,00	1 575,47	54,40	2 348,22
Common investment (e.g. road renovation	2 142,80	2 142,80	2 142,80	2 142,80
Total investment cost	4 222,80	11 968,27	6 773,20	8 241,02
Cohesion own risk	100,00	20,00	20,00	20,00
Investment cost using cohesion found	4 222,80	2 393,65	1 354,64	1 648,20
Operating cost year				
Fuel cost	217,68	71,08	16,15	51,31
Maintenance costs	130,75	236,86	200,22	263,76
Driver costs	220,50	220,50	220,50	220,50
Health cost	76,94	2,81	10,58	27,49
Total operating cost	645,87	531,26	447,45	563,06

	Dieselbus/now	FCHBus	E-Bus	Trolleybus	Car eqiv.
Pollution Isle (NOx equivalent kg/year)					
CO2 emission	91,2384	3,42E-10	14,89981935	47,3472553	371,6064
CO emission	39,9168	0	0	0	193,8816
SO2 emission	0	5,43E-07	1,970087226	6,260359311	0

THC emission	24,92763429	0	0	0	41,54605714
PM emission	0	3,28E-06	81,05501729	257,5690688	0
NOx emission	1155,6864	4,56E-07	46,35499355	147,302572	1077,12
Noise emission	177,0709248	53,04	53,0380224	53,0380224	1001,829312
Total	1488,840159	53,03802668	197,3179398	511,5172778	2685,983369

Pollution all (NOx equivalent kg/year)

CO2 emission	910,17792	3,53332E-09	153,8702652	488,9545674	4985,84202
CO emission	398,20284	0	0	0	2601,30888
SO2 emission	0	5,6062E-06	20,34506839	64,65065947	0
THC emission	248,6736103	0	0	0	557,4233314
PM emission	0	3,39198E-05	837,0542425	2659,912847	0
NOx emission	11528,92032	4,71109E-06	478,7074916	1521,191987	14451,716
Noise emission	1766,427798	547,7230546	547,7230546	547,7230546	13441,54105
Total	14852,40249	547,7230989	2037,700122	5282,433116	36037,83128

Pollution (NOx equivalent kg/year) in isle

CO2 emission	91,2384	0,00E+00	0	0	371,6064
CO emission	39,9168	0,00E+00	0	0	193,8816
SO2 emission	0	0,00E+00	0	0	0
THC emission	24,92763429	0,00E+00	0	0	41,54605714
PM emission	0	0,00E+00	0	0	0
NOx emission	1155,6864	0,00E+00	0	0	1077,12
Noise emission	177,0709248	53,04	53,04	53,04	1001,829312
Total	1488,840159	53,0380224	53,0380224	53,0380224	2685,983369

Pollution (NOx equivalent kg/year) in isle and inner town

CO2 emission	910,17792	0	0	0	4985,84202
CO emission	398,20284	0	0	0	2601,30888

SO2 emission	0	0	0	0	0
THC emission	248,6736103	0	0	0	557,4233314
PM emission	0	0	0	0	0
NOx emission	11528,92032	0	0	0	14451,716
Noise emission	1766,427798	547,7230546	547,7230546	547,7230546	13441,54105
Total	14852,40249	547,7230546	547,7230546	547,7230546	36037,83128

* * *

Appendix 4.

Reference calculation

We publishing here so called reference calculation to help check our calculation method. Reason for, the detailed calculation of project are more hundred page long.

H2 (FCHbus route) fuel production build

H2 (FCHbus route) fuel production build	unit	value
H2 production limit	kg/day	2 092,00
H2 production real	kg/day	520,00
H2 storage	HUF/kg	141 240,00
H2 storage capacity	kg	6 000,00
H2 storage duration	day	2,00
H2 factory	HUF	423 625 620,00
H2 storage	HUF	847 440 000,00
H2 refuelling station	HUF	114 400 000,00
H2 tank-truck	HUF	70 000 000,00
Total fuel production and refuelling investment	HUF	1 455 465 620,00

H2 (FCHbus route) production

H2 (FCHbus route) production	unit	value
H2 electrolysis energy consumption	kwh/kg	50,00
H2 production cost	HUF/kg	600,00
H2 storage operating cost	HUF/kg	75,24
H2 storage operating cost	HUF/year	82 387 800,00
H2 fuelling cost	HUF/kg	79,20
H2 gas flow trough	kg/year	189 800,00
H2 refuelling cost	HUF/year	15 032 160,00
H2 total cost	HUF/kg	754,44
H2 total cost	USD/kg	3,429272727

H2 total cost	EUR/kg	2,557423729

Base data

Base data	unit	value
EUR to HUF exchange rate		295
USD to HUF exchange rate		220
AUD to HUF exchange rate		230
CAD to HUF exchange rate		221
CO2 quota	EUR/t	15
Diesel fuel cost	HUF/l	410
LPG fuel cost	HUF/l	220,66
CNG fuel cost	HUF/kg	316,24
Current's cost	HUF/kwh	17
Current's cost waste	HUF/kwh	12
H2 cost	HUF/kg	754,44
Gas power plant CO2 emission	kg/kwh	0,6
Gas power plant SO2 emission	kg/kwh	0,00005
Gas power plant PM emission	kg/kwh	0,00034
Gas power plant NOx emission	kg/kwh	0,0014
Energy ratio of gas power plant to null emission type	%	36
CO2 emission at power production	kg/kwh	0,216
SO2 emission at power production	kg/kwh	0,000018
PM emission at power production	kg/kwh	0,000122
NOx emission at power production	kg/kwh	0,000504
CO2 emission at real green power production	kg/kwh	1,00E-12
SO2 emission at real green power production	kg/kwh	1,00E-12
PM emission at real green power production	kg/kwh	1,00E-12
NOx emission at real green power production	kg/kwh	1,00E-12
CO health cost	EUR/kg	3
SO2 health cost	EUR/kg	23,8
PM health cost	EUR/kg	144
NOx health cost	EUR/kg	20
NMHC health cost	EUR/kg	3,857143
CO2 danger correction factor	n	0,00075
CO danger correction factor	n	0,15
SO2 danger correction factor	n	1,19
PM danger correction factor	n	7,2

NOx danger correction factor	n	1
NMHC danger correction factor	n	0,192857
Noise car health risk at day	EUR/km	0,0076
Noise car health risk at night	EUR/km	0,0139
Noise bus health risk at day	EUR/km	0,0381
Noise bus health risk at night	EUR/km	0,0695
Night to day ratio	%	27
Day multiplier	n	0,73
Night multiplier	n	0,27
Noise car health cost average	EUR/km	0,009301
Noise bus health cost average	EUR/km	0,046578
Noise E-bus health cost average	EUR/km	0,013952
State related health cost	%	87

Calculation route data

Calculation route data	unit	value
Follow time average	min	10
Follow time minimal	min	6
Route length	km	10
Duration max	min	25
Operating time	hour	18
Operating days in a year	n	360
Vehicle spare ratio	%	130
Average number of passengers vehicle	n	34
Average number of passengers car	n	1,2
Average number of passengers cogwheel train	n	83
Do a distance for one vehicle round-trip	km	20
Round trip for route in hour	n	6
Round trip for route in day	n	108
Round trip for route in year	n	38880
Do a distance for route in hour	km	120
Do a distance for route in day	km	2160
Do a distance for route in year	km	777600
Worst speed for route	kmh	24
Minimal number of vehicle need for route	n	9

Run of vehicle	km/day	240
Run of vehicle	km/year	86400
Number of vehicle need for route	n	12
Driver work	day/year	320
Driver work	hour/day	8
Drivers need for route	n/day	21
Drivers need for route	n/year	24
Drivers payment and other costs for route	HUF/year	5 250 000
Total driver cost for route	HUF/year	126 000 000
Bus to car passenger ratio	n	28,33333333
Bus to cogwheel train passenger ratio	n	0,409638554

Car 'route' fuel cost

Car 'route' fuel cost	unit	value
Consumption vehicle	l/100km	7,00
Consumption vehicle	l/km	0,07000
Consumption vehicle	l/round-trip	1,40
Consumption 'route'	l/hour	8,40
Consumption 'route'	l/day	151,20
Consumption 'route'	l/year	54 432,00
Fuel cost 'route'	HUF/km	28,70
Fuel cost 'route'	HUF/year	22 317 120,00
Fuel cost 'route'	EUR/year	75 651,25
Maintenance cost 'route'	HUF/km	9,00
Maintenance cost 'route'	HUF/year	6 998 400,00
Cost of one vehicle	HUF	3 500 000,00
Vehicle purchase cost 'route'	HUF	42 000 000,00

Bus equivalent costs:

Fuel cost route	HUF/year	632 318 400,00
Fuel cost route	EUR/year	2 143 452,20
Maintenance cost route	HUF/year	198 288 000,00

Vehicle purchase cost route	HUF	1 190 000 000,00

Car 'route' CO2 cost

Car 'route' CO2 cost	unit	value
Diesel CO2 emission vehicle	kg/km	0,23000
Diesel CO emission vehicle	kg/km	0,00060
Diesel THC emission vehicle	kg/km	0,00010
Diesel NOx emission vehicle	kg/km	0,00050
CO2 emission vehicle	kg/round-trip	4,60
CO2 emission 'route'	kg/hour	27,60
CO2 emission 'route'	kg/day	496,80
CO2 emission 'route'	kg/year	178 848,00
CO emission 'route'	kg/year	466,56
THC emission 'route'	kg/year	77,76
NOx emission 'route'	kg/year	388,80
CO2 cost 'route'	EUR/year	2 682,72
CO2 cost 'route'	HUF/year	791 402,40
CO health cost 'route'	EUR/year	1 399,68
THC health cost 'route'	EUR/year	299,93
NOx health cost 'route'	EUR/year	7 776,00
Noise health cost 'route'	EUR/year	7 232,46
Total health cost 'route'	EUR/year	16 708,07
Total health cost 'route'	HUF/year	4 928 880,36
State related part of total health cost 'route'	HUF/year	4 288 125,92
NOx equivalent CO2 emission 'route'	kg/year	134,14
NOx equivalent CO emission 'route'	kg/year	69,98
NOx equivalent THC emission 'route'	kg/year	15,00
NOx equivalent NOx emission 'route'	kg/year	388,80
NOx equivalent noise emission 'route'	kg/year	361,62

Bus equivalent costs:

CO2 emission route	kg/hour	782,00
CO2 emission route	kg/day	14 076,00
CO2 emission route	kg/year	5 067 360,00
CO emission route	kg/year	13 219,20
THC emission route	kg/year	2 203,20

NOx emission route	kg/year	11 016,00
CO2 cost route	EUR/year	76 010,40
CO2 cost route	HUF/year	22 423 068,00
CO health cost route	EUR/year	39 657,60
THC health cost route	EUR/year	8 498,06
NOx health cost route	EUR/year	220 320,00
Noise health cost route	EUR/year	204 919,63
Total health cost route	EUR/year	473 395,29
Total health cost route	HUF/year	139 651 610,30
State related part of total health cost route	HUF/year	121 496 900,96
NOx equivalent CO2 emission route	kg/year	3 800,52
NOx equivalent CO emission route	kg/year	1 982,88
NOx equivalent THC emission route	kg/year	424,90
NOx equivalent NOx emission route	kg/year	11 016,00
NOx equivalent noise emission route	kg/year	10 245,98

Diesel bus route fuel cost

Diesel bus route fuel cost	unit	value
Consumption vehicle	l/100km	70,00
Consumption vehicle	l/km	0,70000
Consumption vehicle	l/round-trip	14,00
Consumption route	l/hour	84,00
Consumption route	l/day	1 512,00
Consumption route	l/year	544 320,00
Fuel cost route	HUF/km	287,00
Fuel cost route	HUF/year	223 171 200,00
Fuel cost route	EUR/year	756 512,54
Maintenance cost route	HUF/km	172,38
Maintenance cost route	HUF/year	134 042 688,00
Cost of one vehicle	HUF	80 000 000,00
Vehicle purchase cost route	HUF	960 000 000,00

Diesel bus route CO_2 emission cost

Diesel bus route CO2 emission cost	unit	value
Diesel bus CO2 emission vehicle	kg/km	1,60000
Diesel bus CO emission vehicle	kg/km	0,00350
Diesel bus THC emission vehicle	kg/km	0,00170
Diesel bus NOx emission vehicle	kg/km	0,01520
CO2 emission vehicle	kg/round-trip	32,00
CO2 emission route	kg/hour	192,00
CO2 emission route	kg/day	3 456,00
CO2 emission route	kg/year	1 244 160,00
CO emission route	kg/year	2 721,60
THC emission route	kg/year	1 321,92
NOx emission route	kg/year	11 819,52
CO2 cost route	EUR/year	18 662,40
CO2 cost route	HUF/year	5 505 408,00
CO health cost route	EUR/year	8 164,80
THC health cost route	EUR/year	5 098,83
NOx health cost route	EUR/year	236 390,40
Noise health cost route	EUR/year	36 219,05
Total health cost route	EUR/year	285 873,09
Total health cost route	HUF/year	84 332 560,69
State related part of total health cost route	HUF/year	73 369 327,80
NOx equivalent CO2 emission route	kg/year	933,12
NOx equivalent CO emission route	kg/year	408,24
NOx equivalent THC emission route	kg/year	254,94
NOx equivalent NOx emission route	kg/year	11 819,52
NOx equivalent noise emission route	kg/year	1 810,95

Trolleybus route fuel cost

Trolleybus route fuel cost	unit	value
Consumption vehicle	kwh/km	3,84
Consumption vehicle	kwh/round-trip	76,88
Consumption route	kwh/hour	461,28

Consumption route	kwh/day	8 303,04
Consumption route	kwh/year	2 989 094,40
Fuel cost route	HUF/km	65,35
Fuel cost route	HUF/year	50 814 604,80
Fuel cost route	EUR/year	172 252,90
Maintenance cost vehicle	HUF/km	212,16
Maintenance cost system	HUF/km	123,76
Maintenance cost route	HUF/year	261 211 392,00
Cost of one vehicle	HUF	150 000 000,00
Vehicle purchase cost route	HUF	1 800 000 000,00

Trolleybus route system build cost

Trolleybus route system build cost	unit	value
System build cost anchor	HUF/km	140 000 000,00
Pole build cost	HUF/km	4 800 000,00
Column build cost	HUF/km	114 000 000,00
Will need to build network anchor type	km	5,00
Will need to build network pole type	km	4,00
Will need to build network column type	km	3,00
Will need to build network column + pole type	km	2,00
Total build length overhead wire	km	14,00
Overhead wire build cost	HUF	2 558 800 000,00
Power station cost	HUF/piece	70 000 000,00
Power station requirement	km	5,00
Power station item	n	1,00
Power station existing	n	0,00
Power station will need to build	n	0,00
Total power station build cost	HUF	0,00
Total system build cost	HUF	2 558 800 000,00

Trolleybus route CO2 emission cost

Trolleybus route CO2 emission cost	unit	value

CO_2 emission vehicle	kg/round-trip	16,61
CO_2 emission route	kg/hour	99,64
CO_2 emission route	kg/day	1 793,46
CO_2 emission route	kg/year	645 644,39
SO_2 emission route	kg/year	53,80
PM emission route	kg/year	365,87
NO_x emission route	kg/year	1 506,50
CO_2 cost route	EUR/year	9 684,67
CO_2 cost route	HUF/year	2 856 976,43
SO_2 health cost route	EUR/year	1 280,53
PM health cost route	EUR/year	52 684,58
NO_x health cost route	EUR/year	30 130,07
Noise health cost route	EUR/year	10 848,69
Total health cost route	EUR/year	94 943,87
Total health cost route	HUF/year	28 008 441,13
State related part of total health cost route	HUF/year	24 367 343,79
NO_x equivalent CO_2 emission route	kg/year	484,23
NO_x equivalent SO_2 emission route	kg/year	64,03
NO_x equivalent PM emission route	kg/year	2 634,23
NO_x equivalent NO_x emission route	kg/year	1 506,50
NO_x equivalent Noise emission route	kg/year	542,43

Ebus route fuel cost

Ebus route fuel cost	unit	value
Consumption vehicle	kwh/km	1,21
Consumption vehicle	kwh/round-trip	24,19
Consumption route	kwh/hour	145,16
Consumption route	kwh/day	2 612,90
Consumption route	kwh/year	940 645,16
Fuel cost route	HUF/km	20,56
Fuel cost route	HUF/year	15 990 967,74
Fuel cost route	EUR/year	54 206,67
Maintenance cost route	HUF/km	255,00
Maintenance cost route	HUF/year	198 288 000,00
Cost of one vehicle	HUF	176 000 000,00

Safe driving range	km	130,00
Charging time	hour	3,00
Additional vehicle needs route	n	1,00
Vehicle purchase cost route	HUF	2 288 000 000,00

Ebus route CO2 emission cost

Ebus route CO2 emission cost	unit	value
CO2 emission vehicle	kg/round-trip	5,23
CO2 emission route	kg/hour	31,35
CO2 emission route	kg/day	564,39
CO2 emission route	kg/year	203 179,35
SO2 emission route	kg/year	16,93
PM emission route	kg/year	115,13
NOx emission route	kg/year	474,09
CO2 cost route	EUR/year	3 047,69
CO2 cost route	HUF/year	899 068,65
SO2 health cost route	EUR/year	402,97
PM health cost route	EUR/year	16 579,44
NOx health cost route	EUR/year	9 481,70
Noise health cost route	EUR/year	10 848,69
Total health cost route	EUR/year	37 312,80
Total health cost route	HUF/year	11 007 275,22
State related part of total health cost route	HUF/year	9 576 329,44
NOx equivalent CO2 emission route	kg/year	152,38
NOx equivalent SO2 emission route	kg/year	20,15
NOx equivalent PM emission route	kg/year	828,97
NOx equivalent NOx emission route	kg/year	474,09
NOx equivalent Noise emission route	kg/year	542,43

FCHbus route fuel cost

FCHbus route fuel cost	unit	value
Consumption vehicle	kg/100km	12,00
Consumption vehicle	kg/km	0,12
Consumption vehicle	kwh/km	6,00

Consumption vehicle	kg/round-trip	2,40
Consumption route	kg/hour	14,40
Consumption route	kg/day	259,20
Consumption route	kg/year	93 312,00
Consumption vehicle	kwh/round-trip	120,00
Consumption route	kwh/hour	720,00
Consumption route	kwh/day	12 960,00
Consumption route	kwh/year	4 665 600,00
Fuel cost route	HUF/km	90,53
Fuel cost route	HUF/year	70 398 305,28
Fuel cost route	EUR/year	238 638,32
Maintenance cost route	HUF/km	301,67
Maintenance cost route	HUF/year	234 574 704,00
Cost of one vehicle	HUF	330 000 000,00
Safe driving range	km	250,00
Charging time	hour	0,50
Additional vehicle needs route	n	0,00
Vehicle purchase cost route	HUF	3 960 000 000,00

FCHbus route CO2 emission cost

FCHbus route CO2 emission cost	unit	value
CO2 emission vehicle	kg/round-trip	1,20E-10
CO2 emission route	kg/hour	7,20E-10
CO2 emission route	kg/day	1,30E-08
CO2 emission route	kg/year	4,67E-06
SO2 emission route	kg/year	4,67E-06
PM emission route	kg/year	4,67E-06
NOx emission route	kg/year	4,67E-06
CO2 cost route	EUR/year	7,00E-08
CO2 cost route	HUF/year	2,06E-05
SO2 health cost route	EUR/year	1,11E-04
PM health cost route	EUR/year	6,72E-04
NOx health cost route	EUR/year	9,33E-05
Noise health cost route	EUR/year	10 848,69
Total health cost route	EUR/year	10 848,69
Total health cost route	HUF/year	3 200 362,75
State related part of total health cost route	HUF/year	2 784 315,59

NOx equivalent CO2 emission route	kg/year	0,00
NOx equivalent SO2 emission route	kg/year	0,00
NOx equivalent PM emission route	kg/year	0,00
NOx equivalent NOx emission route	kg/year	0,00
NOx equivalent Noise emission route	kg/year	542,43

* * *