

The modern Trolley Bus-System Facts and Arguments



Content

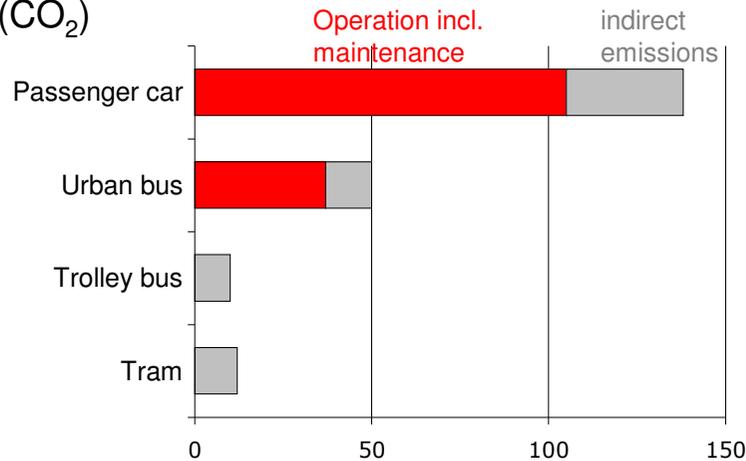
	Page
■ General advantages of the trolley bus	3
■ Emissions - comparison	4
■ Development of energy cost	7
■ System's comparison - cost, lifetimes, capital expenditures	8
■ Cost mechanisms and efficient operations	17
■ Summary and conclusion	19

General advantages of trolley bus systems

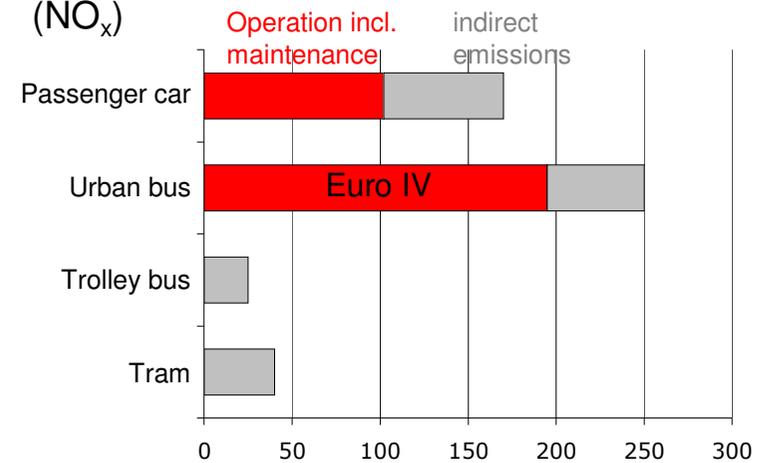
- More popular and accepted by the customer
- Higher comfort compared to diesel/gas bus
- Overhead lines make PT visible, marketing-instrument
- Usage typically higher than for diesel buses (10-20%), higher revenues, socio economic advantage
- Good alternative to tram, trolley bus as „Light-Tram/Lighttram“
- Much cheaper than tram: investment and operation
- No local emissions (zero-emission)
- Silent, in operation and at stations
- Recuperation of braking energy → energy efficiency
- Real cost advantages for traction energy: electric power ↔ diesel

The trolley bus performs very well in emissions

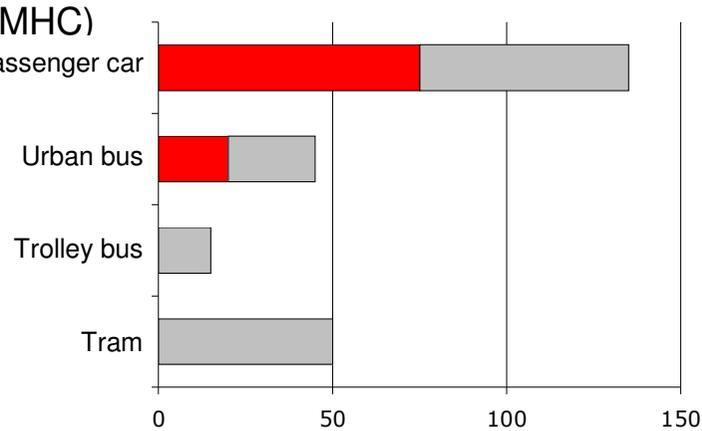
Greenhouse gases (CO₂)



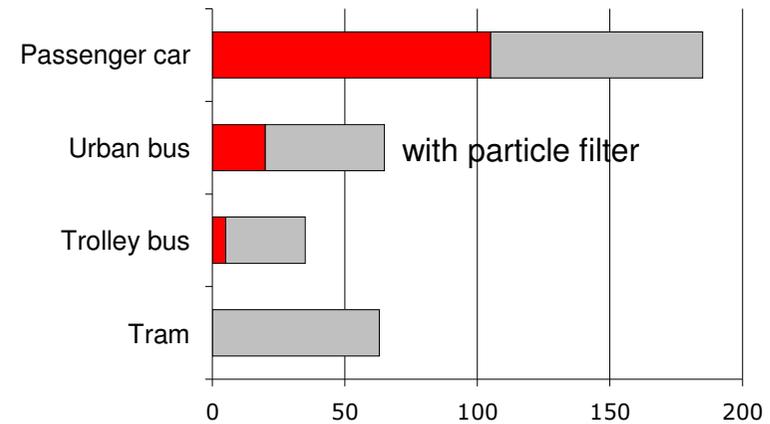
Nitrogen oxide (NO_x)



Hydrocarbon (NMHC)



Particle (< 2,5 µm)



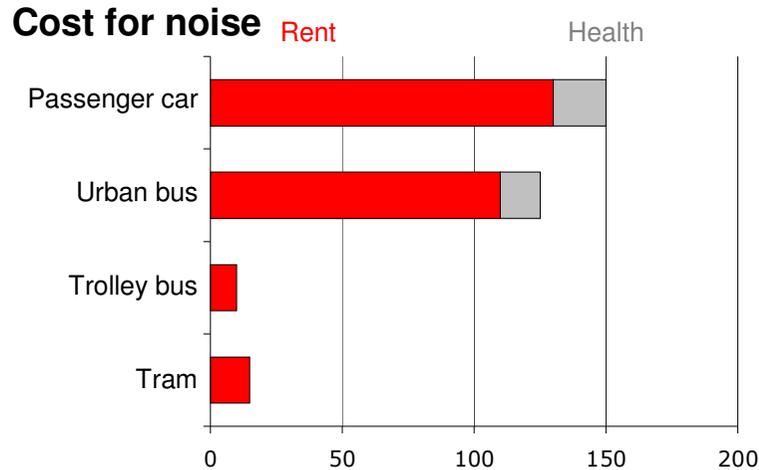
Source: Dr. Peter Marti, Metron Verkehrsplanung AG, Brugg

3. Februar 2013/4

¹ in particular CO₂, more climate-relevant emissions are methane (CH₄) and nitrous oxide (N₂O), which are converted into CO₂-equivalents

Kummler+Matter

The trolley bus performs very well in emissions



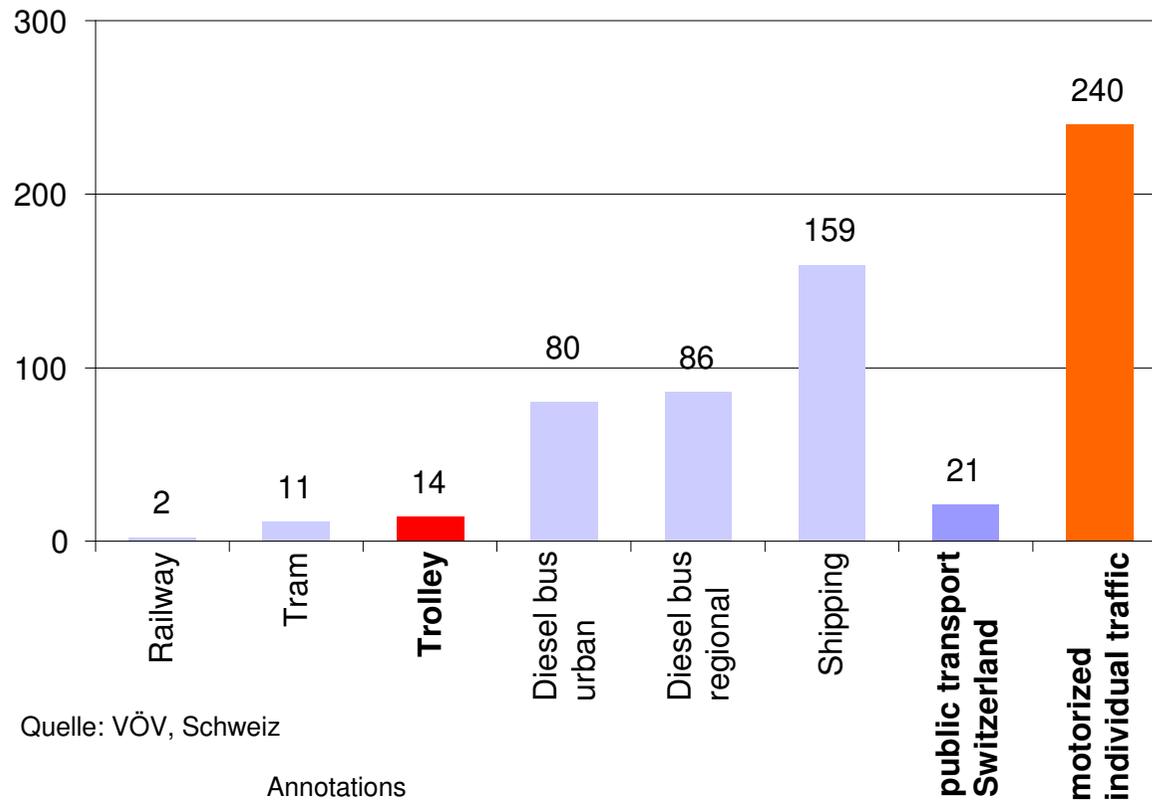
- The trolley bus operates with zero emission locally, in contrast to diesel or gas bus
- This is important for the quality of life in urban areas
- Energy consumption is on the same level than for trams related to one passenger journey
- The trolley bus is the most environment friendly and technically mature mode of public transport

Trolley bus better by ca. ... %

Criteria	Diesel bus	Tram
Energy consumption	40	-30
Greenhouse gases	75	0
Nitrogen oxide	80	40
Hydrocarbon	55	75
Particles - small	20	40
Particles - big	25	60
Noise	90	25
Requirement for land	-25	0

The trolley bus produces less than 20% CO₂ per passenger than a diesel bus

CO₂-emission public transport in Switzerland 2004, per passkm/tonkm in g

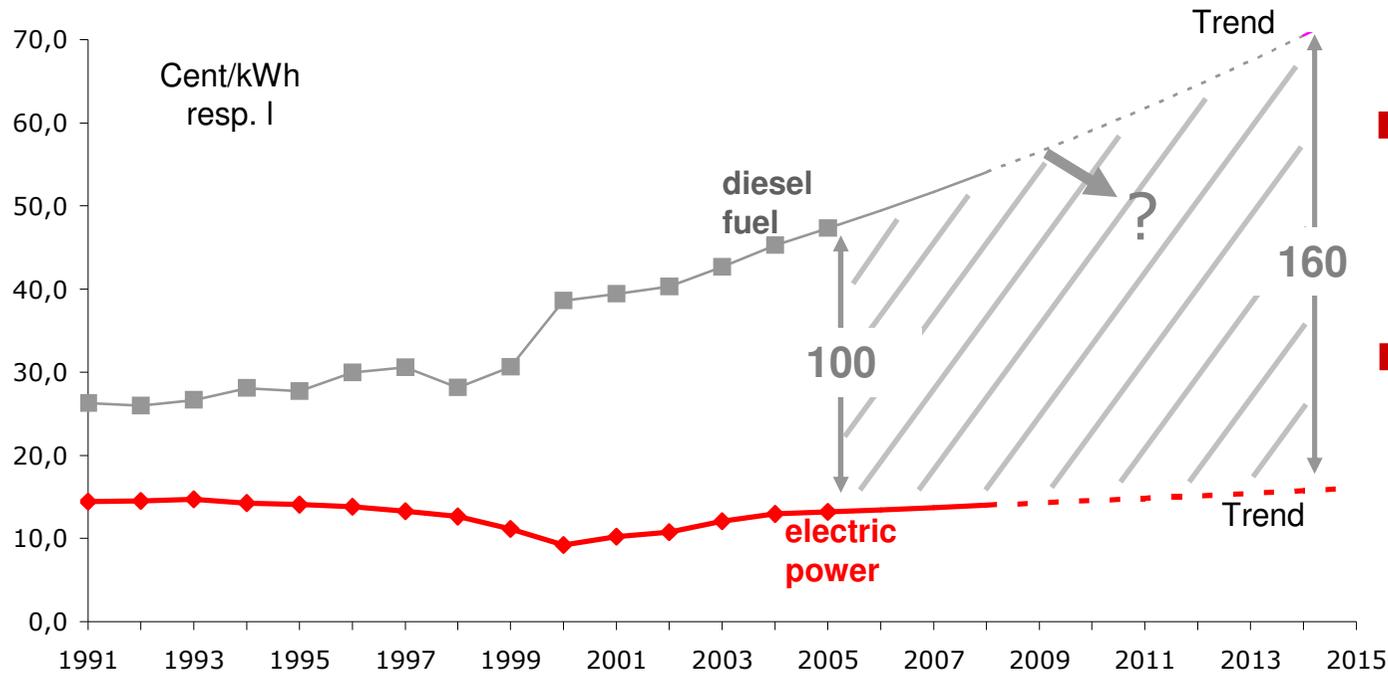


Quelle: VÖV, Schweiz

Annotations

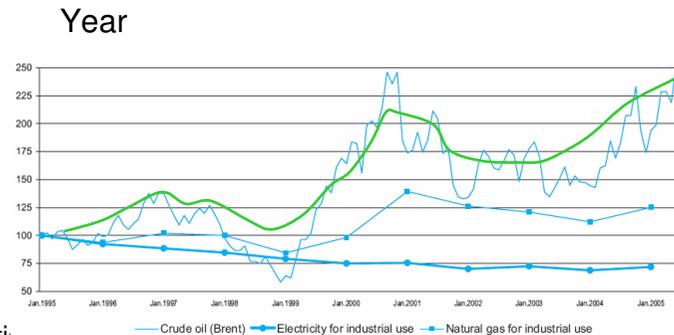
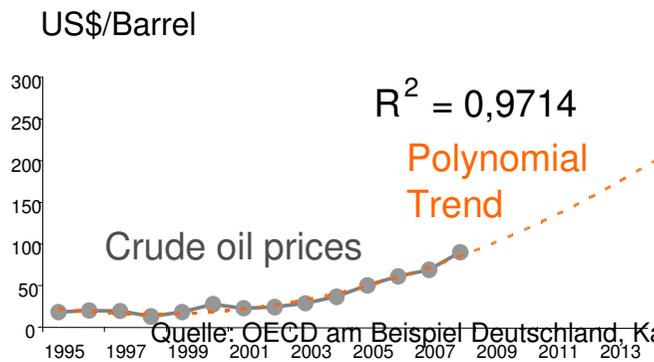
- Railway operations contains passenger and cargo traffic
- Conversion of kWh in railway operations via 90% supply by hydropower and 10% average power mix Switzerland incl. imports, in total 12 g CO₂/kWh
- For tram and trolley bus average power mix of Switzerland is used with 120 g CO₂/kWh
- Factor for conversion of diesel fuel: 2.61 t CO₂ per litre
- Fuel consumption of shipping and diesel locomotives partly estimated

Potential of electrical traction systems - particularly if socio economics will be taken into account



➔ The development of energy prices is crucial for the right decision on PT systems

➔ In ten years the already existing difference might increase by additional 60%



3. Februar 2013/7

Trolley bus systems can be implemented fast and with favourable prices compared to tram systems



- Traction unit, electronics, infrastructure are derived from trams
- Lifetime of assets as similar to trams

➔ Trolley bus = "Light-Tram/Lightram"

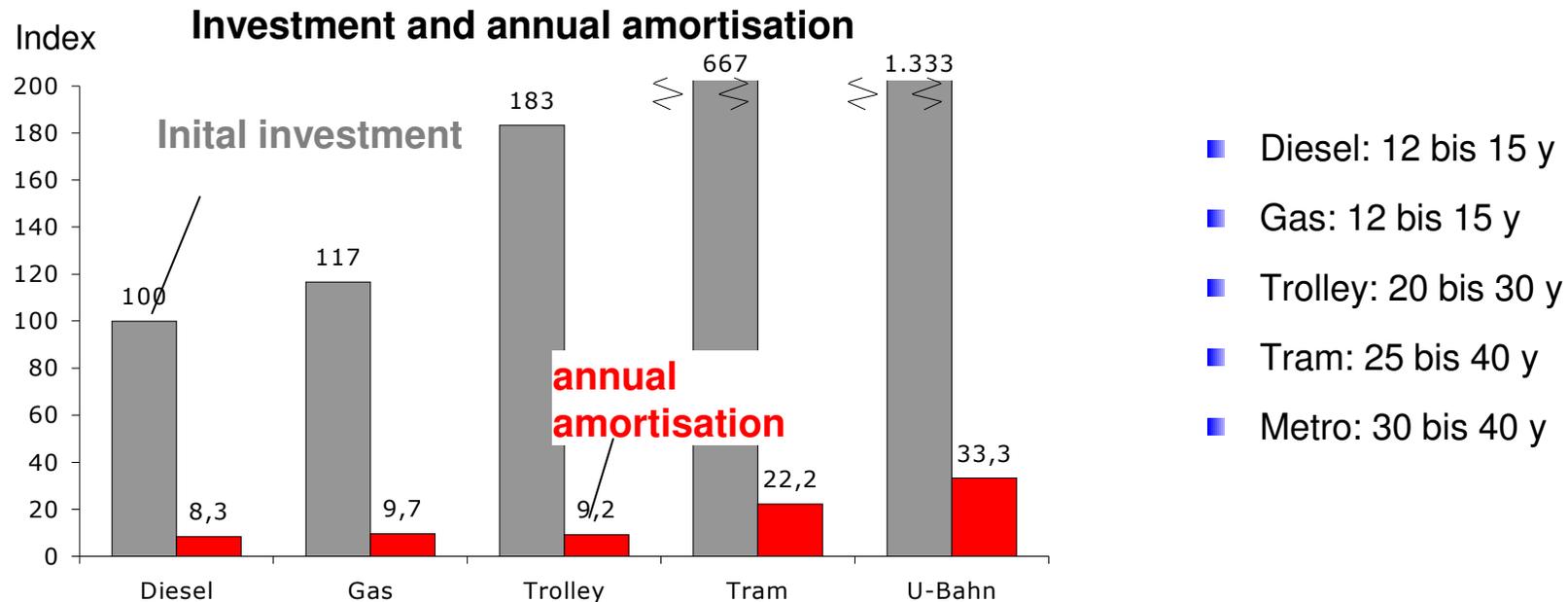
Time	Tram	Trolley bus	Investment	Tram	Trolley bus
Planning	5-10 Y	1-2 Y	Infrastructure	1.000	100
Construction ¹	5-10 Y.	1-2 Y.	Vehicles	300	100
Total	10-20 Y	2-4 Y	Total	1.300	200

↑
↑
five times
↑
↑
six times

Moreover, cost for operations are less than 50% of trams

➔ Trolley buses are often more reasonable than trams (realisation time, investment, cost for operations)

Lifetime, investment and capital expenditures of PT systems



- ➔ For trolley, tram and metro at least one modernisation of interior is carried out during lifetime, typically
- ➔ Diesel and gas show higher wear and tear due to vibrations and more parts with mechanical move
- ➔ Relation of investment and lifetime is much better for trolley than for tram

Clear economic decision Pro trolley bus in Salzburg

Type of cost	Standard articulated trolleybus 20 years	Auxiliary engine articulated trolleybus 20 years	Articulated motorbus 13 years
Fixed costs (vehicle costs)	0.82	0.88	0.74
Capital costs (annuity)	0.74	0.80	0.66
Insurance	0.08	0.08	0.08
Variable costs	0.59	0.59	0.83
Energy	0.16	0.16	0.43
Maintenance incl. internal services	0.43	0.43	0.40
Infrastructure	0.23	0.23	0.01
Total incl. infrastructure	1.64	1.70	1.58
Total excluding rectifiers and overhead conductor lines	1.41	1.47	1.57

Obviously no minimal size of a trolley bus system

Example: Landskrona

Initial targets:

- Zero emissions (NOx, CO2, Particles)
- Less noise
- Stable and reliable

System characteristics:

- Length: 3 km
- buses: 3 Solaris 12 m
- Headway: 7 - 10 min

Investment

Mio. €

infra construction	1,8	relatively high
substation	0,4	
rolling stock	1,6	
other	0,3	
total	4,2	

Annual cost [€/km]

	diesel	trolley	optimized
infrastructure	-	0,72	0,43
rolling stock	0,47	0,70	0,55
energy	0,28	0,12	0,12
operations	1,62	1,86	1,55
total	2,37	3,40	2,65

depending on utilisation; key obstacle for trolley-bus

Schaffhausen (CH) decided PRO trolley bus in 2009
8 vehicles currently, system will be extended

Saving potential for capital cost: 225 T€ annually

without infra 2,22

Supercaps gain a certain cost advantage in operations

Example: Solingen

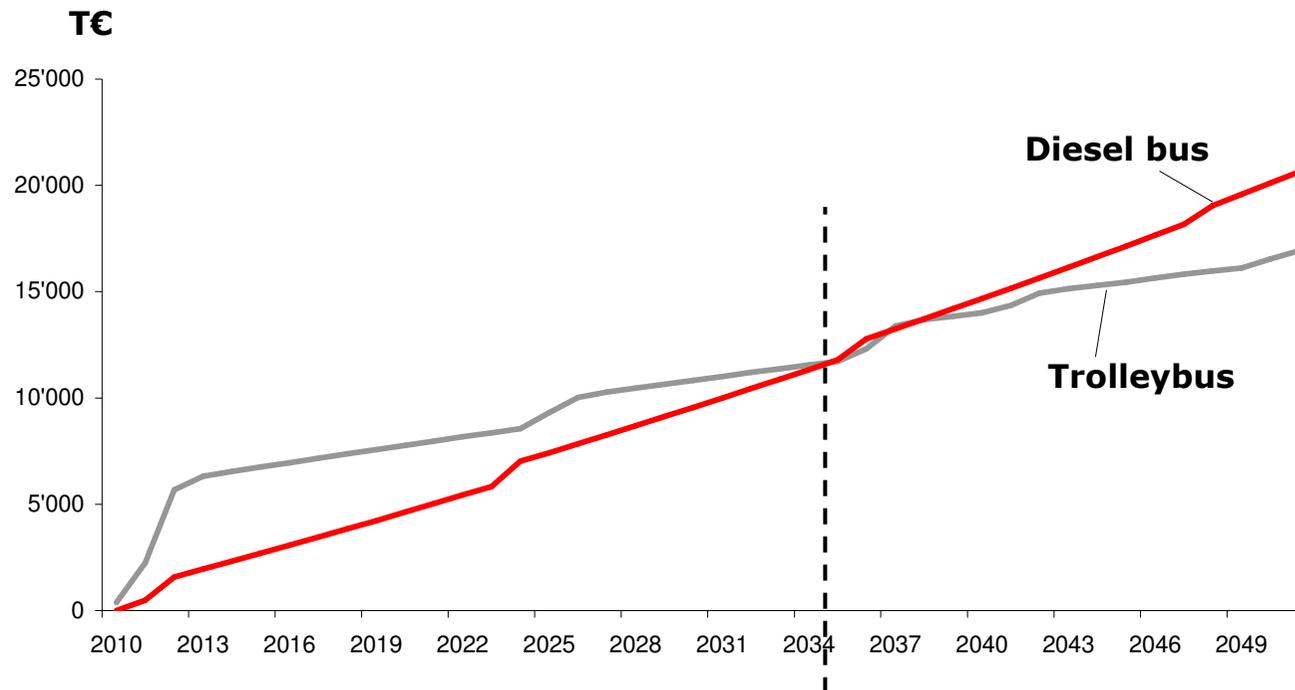
Annual cost [€/km]	Trolley-bus	Trolley-bus with supercaps	Diesel-bus
Energy / fuel	0,28	0,18	0,54
maintenance	0,32	0,32	0,40
capital	0,62	0,62	0,50
infrastructure	0,27	0,27	0,02
other operations	-----	identical	-----
total	1,49	1,39	1,46

depending on difference in energy cost (VAT, special taxes), trolley-bus is cheaper in total

- First time in Solingen, trolley bus can produce services on cost level of diesel-bus
- The developments in recent years support the effect from the supercaps

For sound comparisons LCC-analysis* is necessary

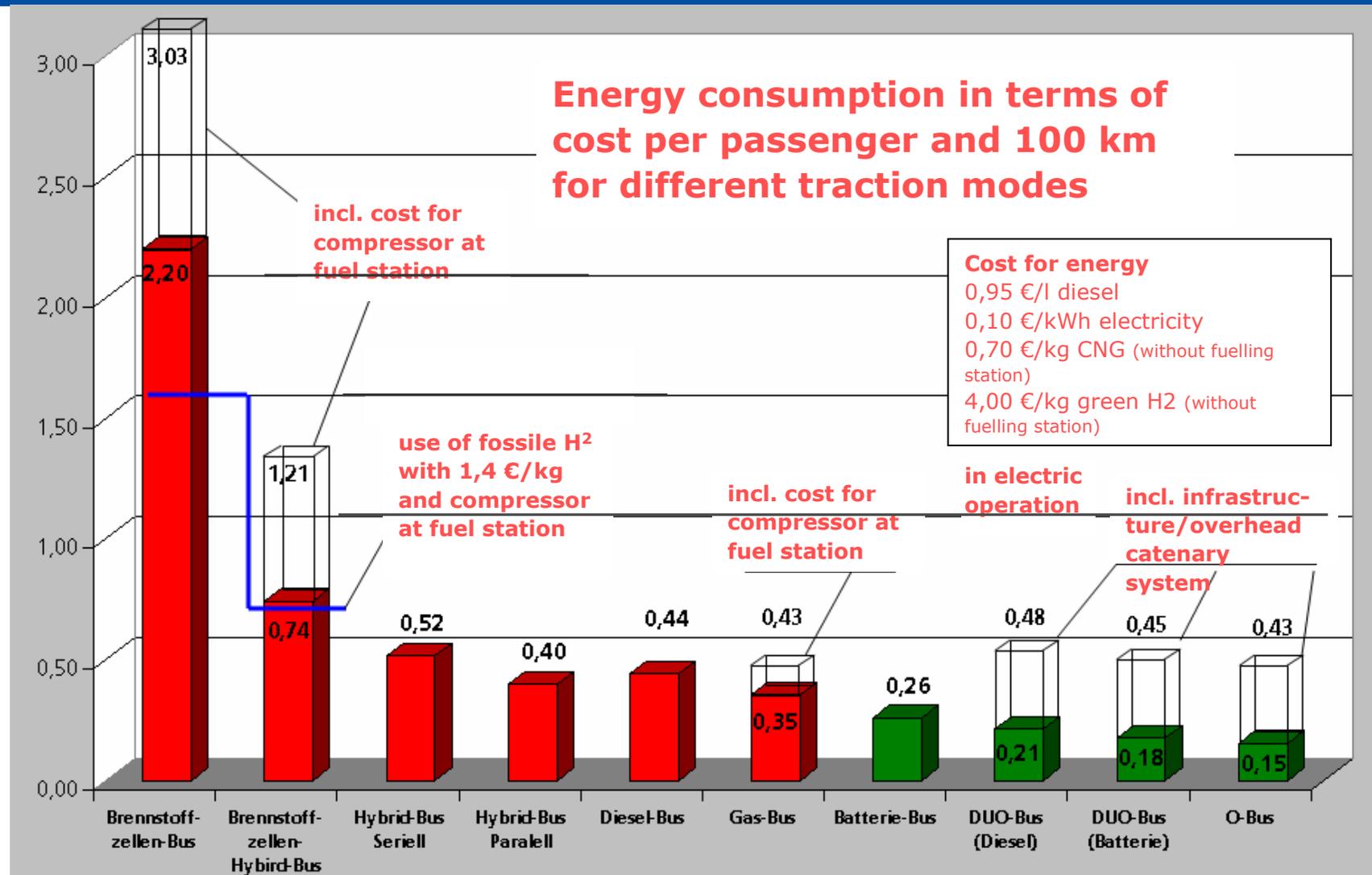
Example: Leipzig - feasibility study



Trolley is a longterm investment due to higher investment

* LCC = life cycle cost

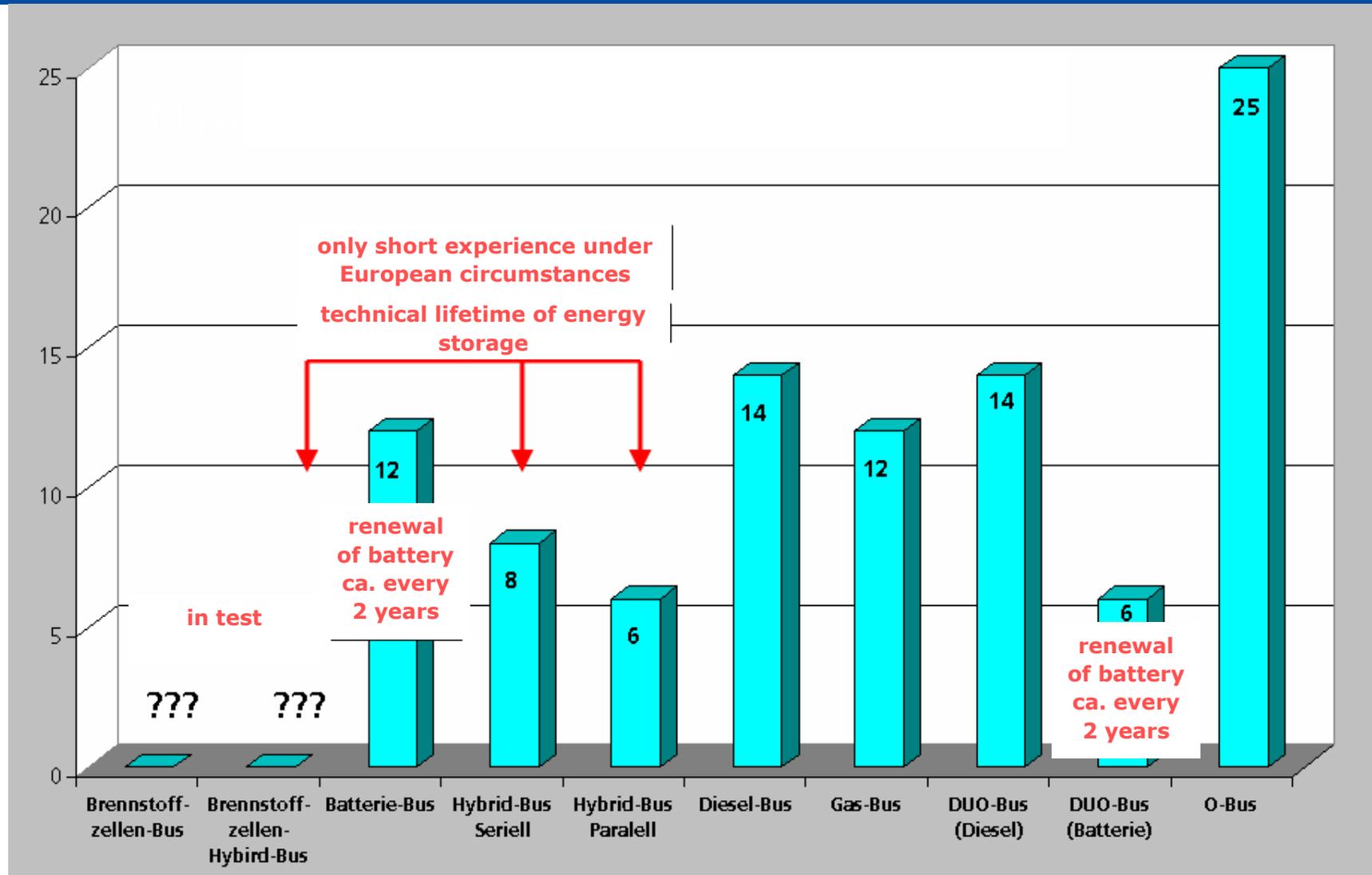
Cost per passenger for traction energy Euro/100 passkm*



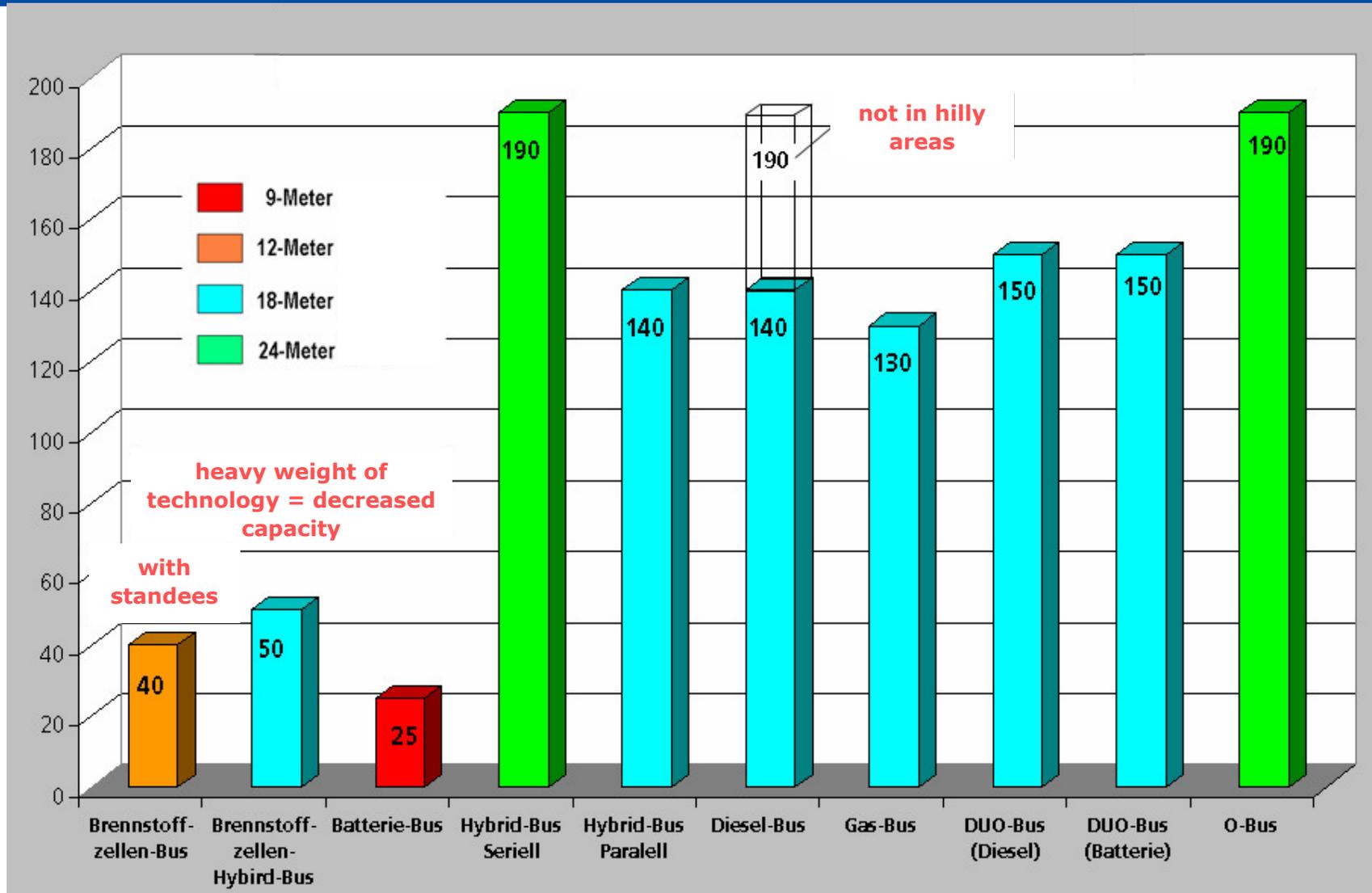
3. Februar 2013/14

* based on national tax rules of Austria

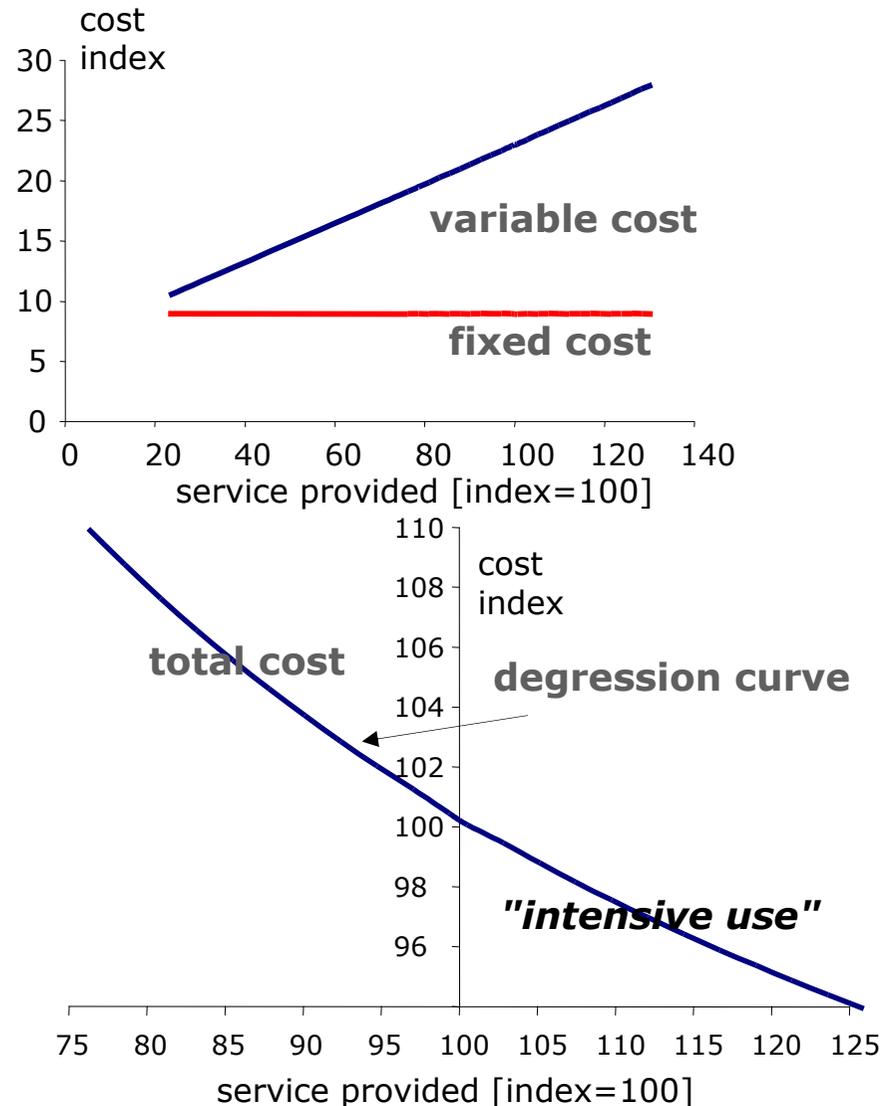
Maximum lifetime at intensive use



Maximum capacity in terms of passengers



Looking at the cost mechanisms the do's and don'ts are getting obvious



- trolley bus with higher proportion of fixed costs than diesel-bus
- hence, stronger effect on fixed cost if services are increased
- in case of tight schedule and short headways, a trolley bus can realise its advantages
- particularly with regard to fuel prices the economic situation gets better for trolley buses

Trolley bus realises clear economic advantages under certain circumstances

- 1. Urban quarter with high building density**
Low noise and no local emissions allow for high quality of life
- 2. Hilly topography**
Recuperation of breaking energy reduces cost
- 3. Compact network and short headways**
Optimal use of investments in infrastructure and vehicles
- 4. High passenger demand**
Capacity of trolley bus are sufficient to substitute tram systems, moreover, higher revenues can be gained ("railway bonus")
- 5. Sustainable development of cities**
The infrastructure defines development corridors and creates sound conditions for private and commercial investors. Price of land, employment and taxes are increased

Summary and conclusion

- Trolley bus systems are not necessarily more expensive than diesel/gas bus systems
- Hybrids are actually much more expensive than trolleys
- Trolley buses are a good alternative to trams, particularly if no tram system is in place
- Business economic advantages are possible for trolley against diesel (gas), if specific requirements are fulfilled
 - high usage of infrastructure and vehicles (fixed cost), which needs good planning (infra and operations)
 - energy cost are developing like the last years
 - opportunities of recuperation are used optimally
 - maintenance is optimised
 - rail bonus for revenues can be achieved

Summary and conclusion

- A high utilisation in terms of services provided is essential for competitive unit cost (€/km)
- Cost advantage of a trolleybus system appears in traction energy in particular
- Do not use diesel buses driving under an existing overhead catenary system
- Socio economic advantages are clear for electrical systems
- Quality of PT depends not on the mode, but on attractiveness of service (low floor, air conditioned, dedicated lanes for speed, etc.)

Trolleybus: Economy, Ecology, Capacity, Priority



3. Februar 2013/21

Kummler+Matter