Fuel cell vehicles and systems for transport of construction materials in cities

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Partners

- **Scania**
- **Skanska**
- **Sveriges Åkeriföretag**
- **Transportföretagen**
- **Vattenfall**
- **Parator Industri AB**
- **AB Volvo**

Background

- **According to the Swedish environmental act of January 1st 2018 the emissions with environmental impact shall be net-zero in 2045**
  - ***A goal is to decrease emissions from domestic transports*** *(air transports excluded)* ***by a least 70 % in 2030 compared with the base-line in 2019***
    - **That means a fossil-free road vehicle fleet in 2030 and a zero emission fleet in 2050**
    - **In order to achieve the ambition that goods transports in the near future will be essentially zero emission continued energy efficiency efforts and a general development of electrified vehicles and drive systems are required**
    - **In the goods transport sector it is likely that short-distance transports in cities and urban areas will be electrified before the long-range transports**
  - ***Over 50 % of the amount of goods transported in Stockholm County is made up of bulk, such as soil, stone, sand and gravel***
    - **Bulk transports in towns and cities are often short (under 100 km, or 60 miles)**
    - **In these transports the vehicle's payload is of great importance**
    - **This means that fuel cells are assumed to be of particular interest in this application**
  - ***In this study the possibility of using hydrogen-powered fuel cell vehicles for bulk freight transports in cities and urban areas therefore was investigated***

Aim

- **The purpose of this study was:**
  - ***To map state-of-the art of the research in the area and to identify the present trends in the same area***
  - ***To investigate how fuel cells and hydrogen could contribute to energy efficient and sustainable transports of bulk goods and construction materials in cities***
  - ***An intention was to compare vehicles equipped with fuel cells with other alternative drive systems and fuels, such as:***
    - ✓ **Battery-electric plug-in vehicles**
    - ✓ **Battery-electric vehicles that can be supported by energy from overhead-wirings of electrified roads**
    - ✓ **Vehicles powered by diesel-engines supplied by biofuels or fossil diesel fuel**
  - ***To investigate which economic incitaments there are for construction and transport companies that transports bulk goods and construction materials in cities to implement and use fuel cell equipped and hydrogen powered vehicles (trucks)***
  - ***To investigate how the infrastructure for hydrogen supply can be designed in order to make it possible to use hydrogen powered vehicles in cities***

Literature review – fuel cell solutions in service

Vision Industries and Balqon 2013: Terminal tractor Vision Zero-TT
(fuelcelltoday.com**)**

Kalmar 2017-2019: Fuel cell 16 tonnes forklift truck
(TFK, 2018)

Toyota 2017: Fuel cell truck for a pilot route between Port of LA and Long Beach
(Toyota Project Portal FCV Truck 01, 2019)

Esoro, Swiss hydrogen and Powercell 2016: Fuel cell truck
(fuelcellworks.com)

BNSF 2010: Fuel cell switch locomotive
(Hess et al, 2010)

Alstom 2018: Fuel cell passenger train Coradia iLINT in service (Alstom, 2018)

Literature review

- **Action ranges and other data for existing fuel-cell equipped and hydrogen powered trucks**

Manufactor/type	**Vehicle-configu-ration**	**Gross-weight** (tonnes)	**Action range** (km)	**Capacity of fuel storage** (kg hydrogen)	**Power of fuel cells** (kW)	**Battery kapacity** (kWh)
NikolaOne	Tractor		800 – 1 600		300	320
NikolaThree	Tractor		500 – 1 200			
Toyota ”Beta”	Tractor	36	480	60		12
Scania (for ASKO)	Truck (lorry)	27	500	33	90	56
Esoro	Truck (lorry)	34	370 – 400	31	100	120
Hyundai	Tractor	34	400	32,9	190	
Kenworth T680 ZECT	Tractor	36	240	30	85	100
US Hybrid & Navistar	Tractor		320	25	80	30

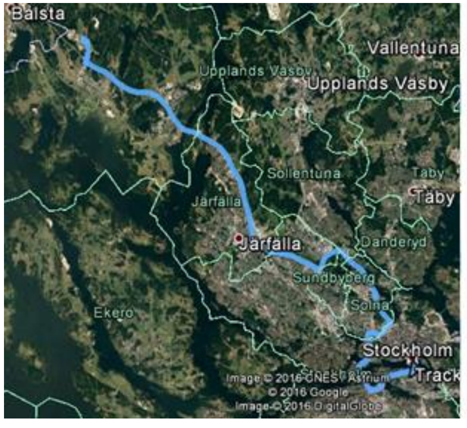
Case studies

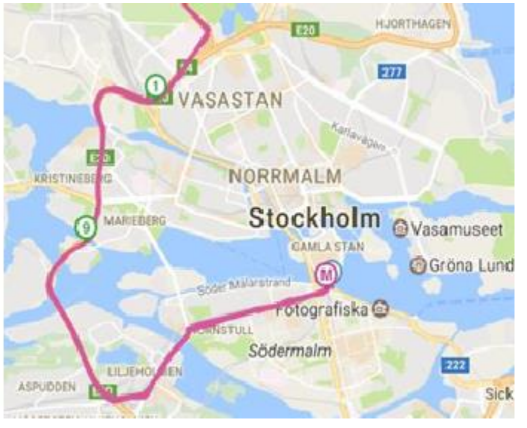
- **In order to investigate if and how fuel cells and hydrogen can contribute to energy-efficient and sustainable transports of bulk in cities and urban areas three different transport schemes in the Stockholm area have been studied**
  - ***Hydrogen-powered vehicles equipped with fuel cells were compared with diesel vehicles powered with biodiesel alternative fossil diesel as well as with other "full-electric" solutions based on the electrified powertrains***
  - ***The "full-electric" systems are represented by battery-electric plug-in vehicles and battery-electric vehicles with the possibility to provide energy during the transport process, from over-head wirings, or similar system solutions for electrified roads***

Case	Transport route	Transported kinds of materials or goods	Load weight at diesel power (tonnes)	Distance *turn and return* (km)	Use of energy *turn and return* (kWh)
A.	Slussen	Soil, rock and landfill	10	96	96
B.	Regeringsgatan	Concrete	12	25	25
C.	Klarastrandsleden	Asphalt	37	89	150

Case assessments

- **Case A: Slussen – Högbotorp (48 km)**
  - ***Energy storage for at least 3 trips (288 km)***





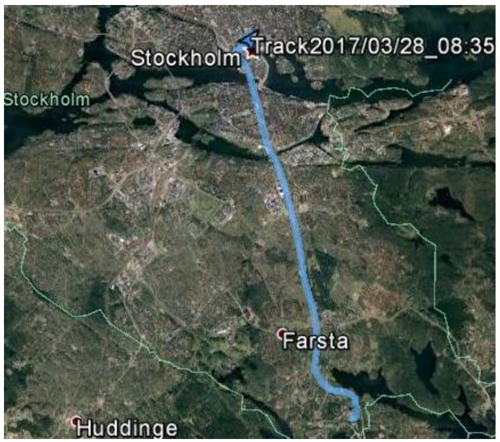
Type of vehicle used in case A (Volvo)

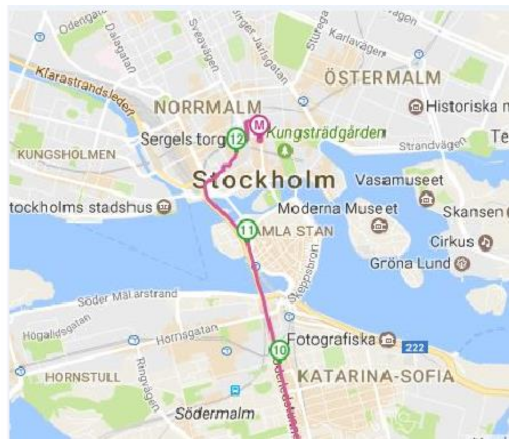
		Loading capacity (tonnes)	Energy consumption (kWh/tonnes)	Energy consumption (reduction)	Carbon-dioxide emissions (kg/tonnes)	Carbon-dioxide emissions (reduction)	Energy costs (kr/tonnes)	Energy costs (reduction)
Hydrogen powered vehicles with fuel-cells[3]		10	19	(29 %)	2[1]/0[2]	(78 %[1]/100 %[2])	26	(38 %)
Battery electric plug-in vehicles	80 % battery capacity used	7.8	15	(44 %)	1[1]/0[2]	(89 %[1]/100 %[2])	12	(71 %)
	40 % battery capacity used	4.9	25	(7 %)	2[1]/0[2]	(78 %[1]/100 %[2])	20	(52 %)
Battery electric vehicles with possibility to external power supply like electrified roads		10	15	(55 %)	1[1]/0[2]	(89 %[1]/100 %[2])	12	(71 %)
Vehicles powered with biodiesel		10	27	(0 %)	1	(89 %)	45	(+7%)
Vehicles powered with fossil diesel fuel		***10***	***27***	***(100 %)***	***7***	***(100 %)***	***42***	***(100 %)***

[1] Electric power according to Swedish Elmix is used
[2] Electric power according to certified fossil free electric energy is used
[3] Costs for a hydrogen refueling-station is included

Case assessments

- **Case B: Farsta – Regeringsgatan (12,5 km)**
  - ***Energy storage for at least 3 trips (75 km)***





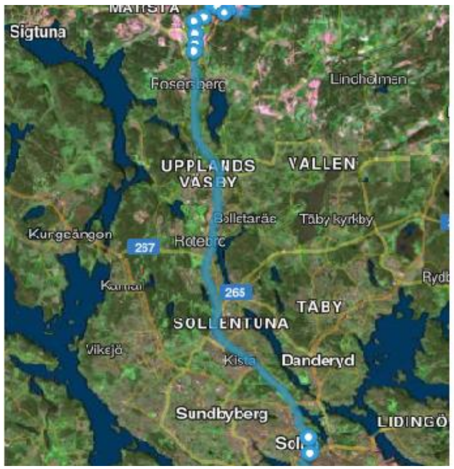
Vehicle used in case B (TFK)

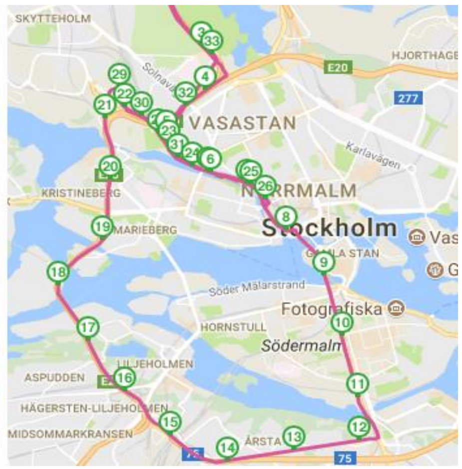
		Loading capacity (tonnes)	Energy consumption (kWh/tonnes)	Energy consumption (reduction)	Carbon-dioxide emissions (kg/tonnes)	Carbon-dioxide emissions (reduction)	Energy costs (kr/tonnes)	Energy costs (reduction)
Hydrogen powered vehicles with fuel-cells[3]		12	4	(33 %)	0.4[1]/0[2]	(73 %[1]/100 %[2])	6	(33 %)
Battery electric plug-in vehicles	80 % battery capacity	12	3	(50 %)	0.2[1]/0[2]	(87 %[1]/100 %[2])	2	(78 %)
	40 % battery capacity	11.2	3	(50 %)	0.2[1]/0[2]	(87 %[1]/100 %[2])	2	(78 %)
Battery electric vehicles with possibility to external power supply like electrified roads		12	3	(50 %)	0.2[1]/0[2]	(87 %[1]/100 %[2])	2	(78 %)
Vehicles powered with biodiesel		12	6	(0 %)	0.3	(80 %)	10	(+11%)
Vehicles powered with fossil diesel fuel		***12***	***6***	***(100 %)***	***1.5***	***(100 %)***	***9***	***(100 %)***

[1] Electric power according to Swedish Elmix is used
[2] Electric power according to certified fossil free electric energy is used
[3] Costs for a hydrogen refueling-station is included

Case assessments

- **Case C: Arlanda – Klarastrandsleden (45 km)**
  - ***Energy storage for at least 3 trips (270 km)***





Vehicle combination used in case C (TFK)

		Loading capacity (tonnes)	Energy consumption (kWh/tonnes)	(reduction)	Carbon-dioxide emissions (kg/tonnes)	(reduction)	Energy costs (kr/tonnes)	(reduction)
Hydrogen powered vehicles with fuel-cells[3]		35.9	8	(27 %)	0.7[1]/0[2]	(90 %[1]/100 %[2])	11	(39 %)
Battery electric plug-in vehicles	80 % battery capacity	32.1	6	(55 %)	0.4[1]/0[2]	(87 %[1]/100 %[2])	5	(72 %)
	40 % battery capacity	27.6	7	(36 %)	0.4[1]/0[2]	(87 %[1]/100 %[2])	5	(72 %)
Battery electric vehicles with possibility to external power supply like electrified roads		35.1	5	(55 %)	0.3[1]/0[2]	(90 %[1]/100 %[2])	4	(78 %)
Vehicles powered with biodiesel		37	11	(0 %)	0.5	(83 %)	19	(+6 %)
Vehicles powered with fossil diesel fuel		***37***	***11***	***(100 %)***	***3.0***	***(100 %)***	***18***	***(100 %)***

[1] Electric power according to Swedish Elmix is used
[2] Electric power according to certified fossil free electric energy is used
[3] Costs for a hydrogen refueling-station is included

Incitements

- **Based on the results of the study a number of incitements might constitute a base for construction companies and transport operators to acquire, implement and use fuel cell equipped and hydrogen powered vehicles that will offer**
  - ***Lower fuel costs compared to fossil diesel and biodiesel and the ability to power vehicles with a fossil-free fuel if the hydrogen is produced by fossil-free electricity***
  - ***Long action ranges in combination with fast hydrogen refueling means that transport routes do not need to be adapted in particular linked to the refueling stations***
  - ***Quiet or silent operations compared to diesel operation***
  - ***Lower maintenance costs compared to diesel operation***
  - ***Compared with battery electric-vehicles, the hydrogen-powered vehicles are better suited for heavy and long-distance transport operations***
- **The cost for the vehicle's propulsion in combination with costs for charging stations, is lower for battery-electric vehicles compared with costs of fuel cell-powered vehicles in combination with costs for hydrogen refueling stations**
  - ***In cases where it is possible to create transport arrangements that are adopted and optimized to the limitations of battery-electric operation this system is preferable***
  - ***In vehicles for bulk goods the weight of the batteries often will decrease the payload***

Results

- **The studied cases and routes indicated that several benefits could be earned with a shift from fossil diesel fuel operations to hydrogen powered transports of construction materials in cities and urban areas**
  - ***The energy consumption* could be decrease *with about 30 %***
  - ***Carbon-dioxide emissions could be decreased, in that case by more than 70 %***
    - **One advantage is that fuel cells can be fueled with hydrogen produced with fossil-free electricity**
  - ***The energy and fuel costs was accounted to be decreased by 30 - 40 %.***
  - ***In bulk goods transports the payload is important and in city-transports heavier fuel-cell powered vehicles, than the concept vehicles that so far have been presented, are needed***
- **If instead battery-electric powered vehicles would be possible to use further energy, costs and environmental benefits could be earned depending on how the energy demand looks like according to transport routes and load weights**
  - ***Battery-electric operation is preferable when the distances and the routings will allows it***
  - ***If the need of energy is essential a large amount of battery capacity is needed which will increase the weight of the vehicle and also reduce the payload***
  - ***A reduced payload will result in more vehicle movements which in the end will raise the energy consumption and increase the environmental impact***

Conclusions

- **In transports of bulk and construction materials in cities and urban areas the total load amount, or payload, is very important, which means that there is a general need of vehicles that are heavier than the fuel cell powered vehicle concepts that has so far been presented**
- **The transport distances and the need of actions ranges are considerably shorter for transports of bulk and construction materials in cities and urban areas than what the presented vehicle concepts today offers**
- **For transports over short distances, and with limited gross weights, when single trucks are used in the majority of cases, it is theoretically possible to use battery-electric operation where vehicles can be charged during breaks and in the night**
- **For transport over longer distances and/or with higher gross weights, and for transports which also requires energy to other systems than propulsion, such as concrete transit rotators, hydrogen power, however, is of interest**
- **One major advantage of hydrogen powered fuel cells are that they involves a quick energy refueling and does not restrict the payload capacity of the vehicles to the same extent as a battery-electric powered drive-system will restrict the capacity**

Thank you!

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