

Scenarios towards the Industrialization of SOFC APUs

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AVL SOFC APU (Auxiliary Power Unit)



Portable power out of diesel fuel
without noise and emissions!



Other markets:



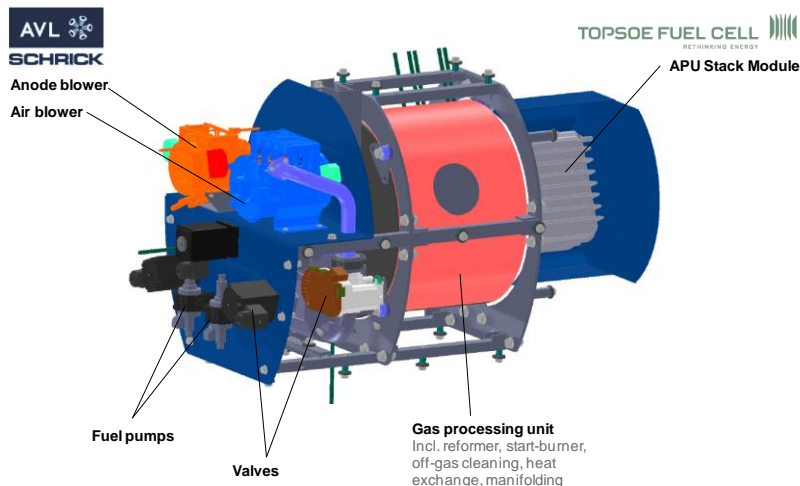
Military



Marine



Camping



Design Targets:

- 3kW electrical power
- 10kW thermal power
- el. efficiency ~35%
- Fuel: road diesel (< 15 ppm S)
- 80L, 75kg
- ~ 55dB(A) noise
- 8000h lifetime
- 300/3000 cold/warm cycles

Overview AVL APU Generations



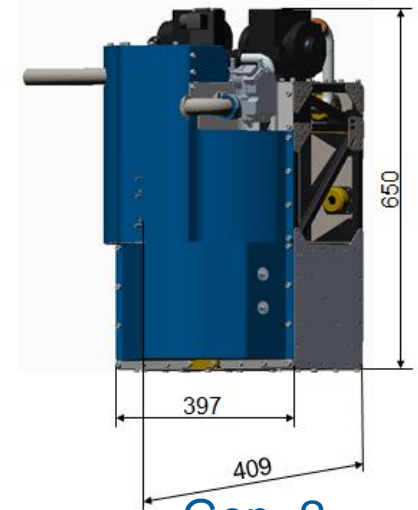
nominated for
Austrian
national prize
2013



Gen. 1.0



Gen. 1.1



Gen. 2



Sep.
2011

*first AVL System
with full
functionality*

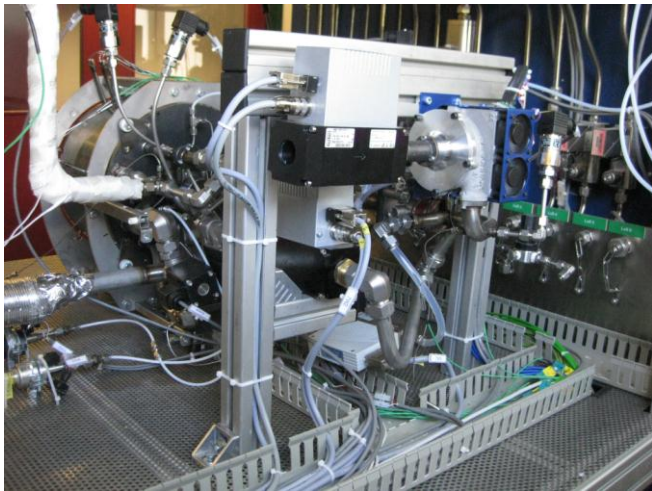
Oct.
2012

*first vehicle
integration*

May
2013

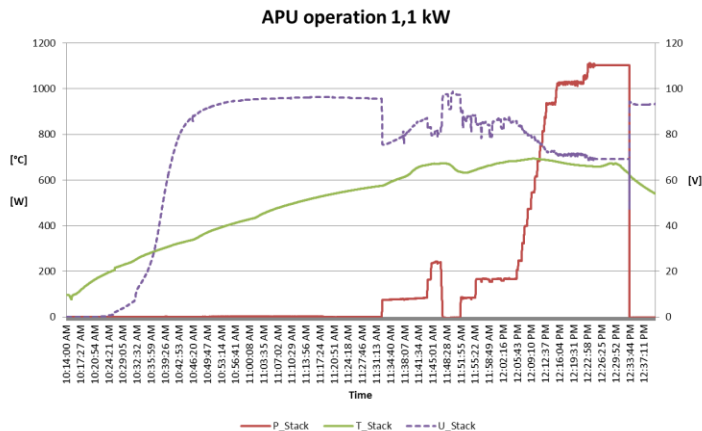
*2 stack design
-25% in size*

Achieved Test Results wit Gen I

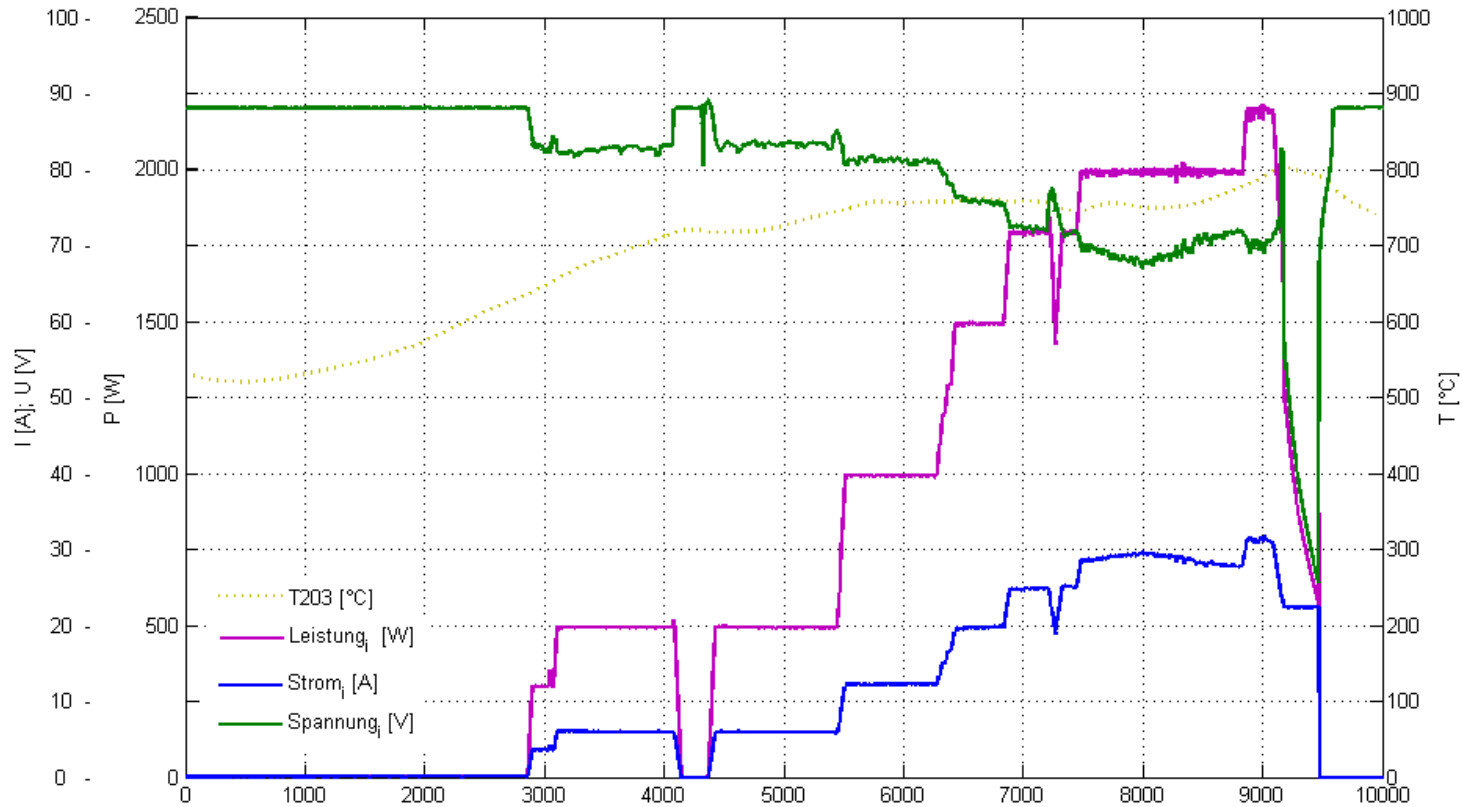


With 1 stack systems:

- ⇒ ~2.2kW gross power output
- ⇒ ~1.8kW net power output
- ⇒ 29% electrical efficiency
- ⇒ start up time ~1h
- ⇒ operation completely without lab infrastructure (inert gas,...)
- ⇒ very reasonable degradation
- ⇒ ~2000h of operation with Gen 0 (stopped) and with Gen I
- ⇒ 50 cold starts / 100 warm starts
- ⇒ <55dB(A) noise level



AVL APU Gen I – 1 Stack System



- ➔ with 1 stack system 2.2/1.8kW achieved, ~2.5/2.2kW possible
- ➔ AVL APU system designed for 3kW, might reach above 4kW of electr. power

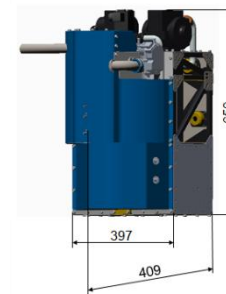
Status and Outlook

	Demonstrated	Target
	Gen I.I	Gen II
Rated el. Power:	2kW	3KW
max. el. Power:	2kW	4kW
Electrical Efficiency¹:	30%	35%
Thermal Power:	12kW	12kW
Fuel Consumption¹:	0.7l/h	0.9l/h
Packaging Space:	750x420x420mm	650x400x400mm
Weight:	90kg	80kg
Noise level:	55dB(A)	<50dB(A)
Start up time³:	40min/60min	30min
Lifetime:	2000h	8000h
Thermal Cycles²:	100/300	300/3000

1...at rated power

2...cold/warm

3...stack level/system level



First 2 Gen II are in operation since mid of June 2013!

BUSINESS CASE:

END USER

(TRUCK OWNER, FLEET OPERATOR)

Assumptions – Reference Scenario

Status April 2013

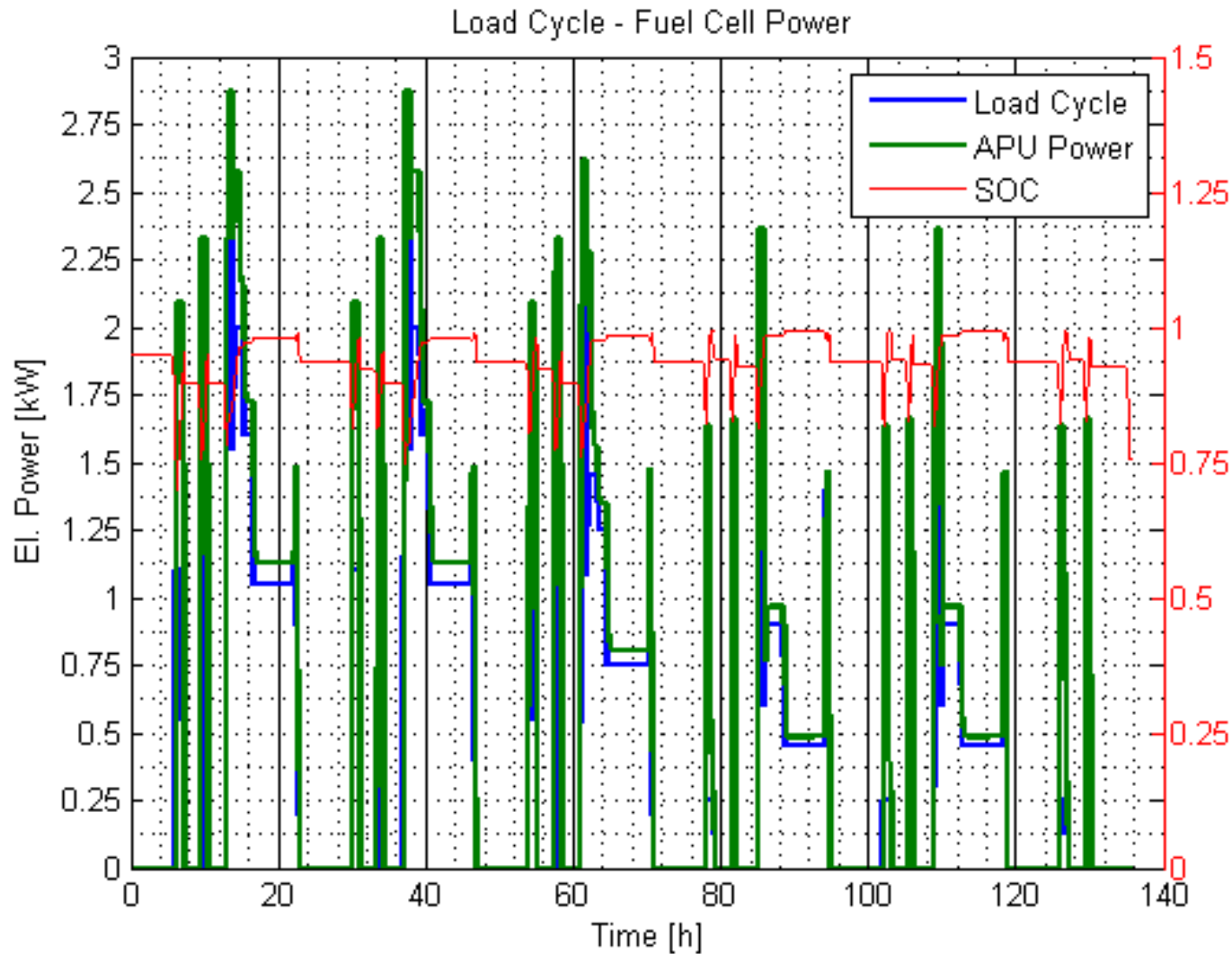
- Idling Time per Week: 30, 40, 50 & 57.83 h

- Diesel price: 3.9 – 5.0 \$/gal (3.9 \$/gal = 0.79 €/l)

- Fuel Consumption (Idling):
 - Truck: 0.75 gal/h (2.84 l/h)
 - ICE APU: measured, improved map
 - SOFC APU: expected efficiency 2016

- Sales price SOFC APU 12.000 \$ (9.230 €)
- Sales price ICE APU 10.000 \$ (7.700 €)

APU Simulation – Reference Scenario (Batt 280 Ah)

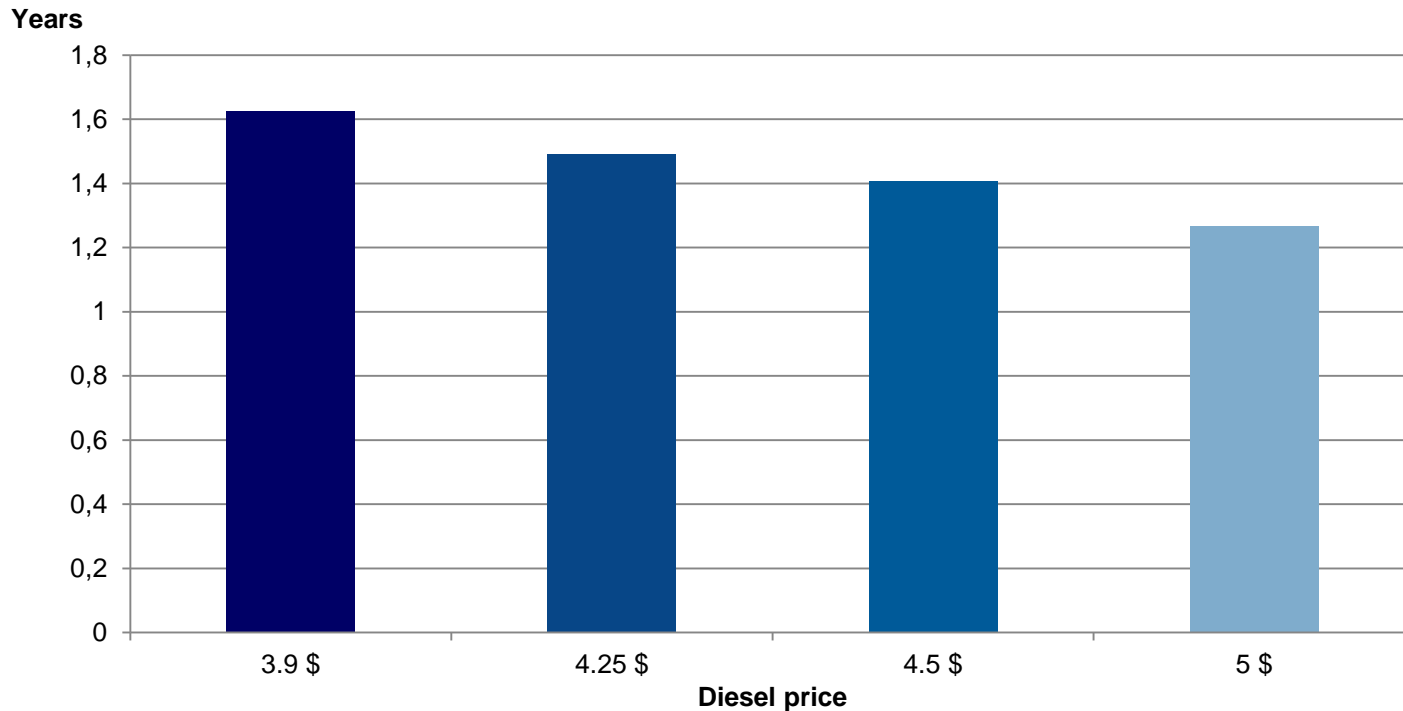


Sensitivity Analyses Fuel Price

Comparison **Truck Idling** vs. **SOFC APU**

Pay back period

- 3,9 \$: 1,62 years
- 4,25 \$: 1,50 years
- 4,5 \$: 1,41 years
- 5 \$: 1,27 years

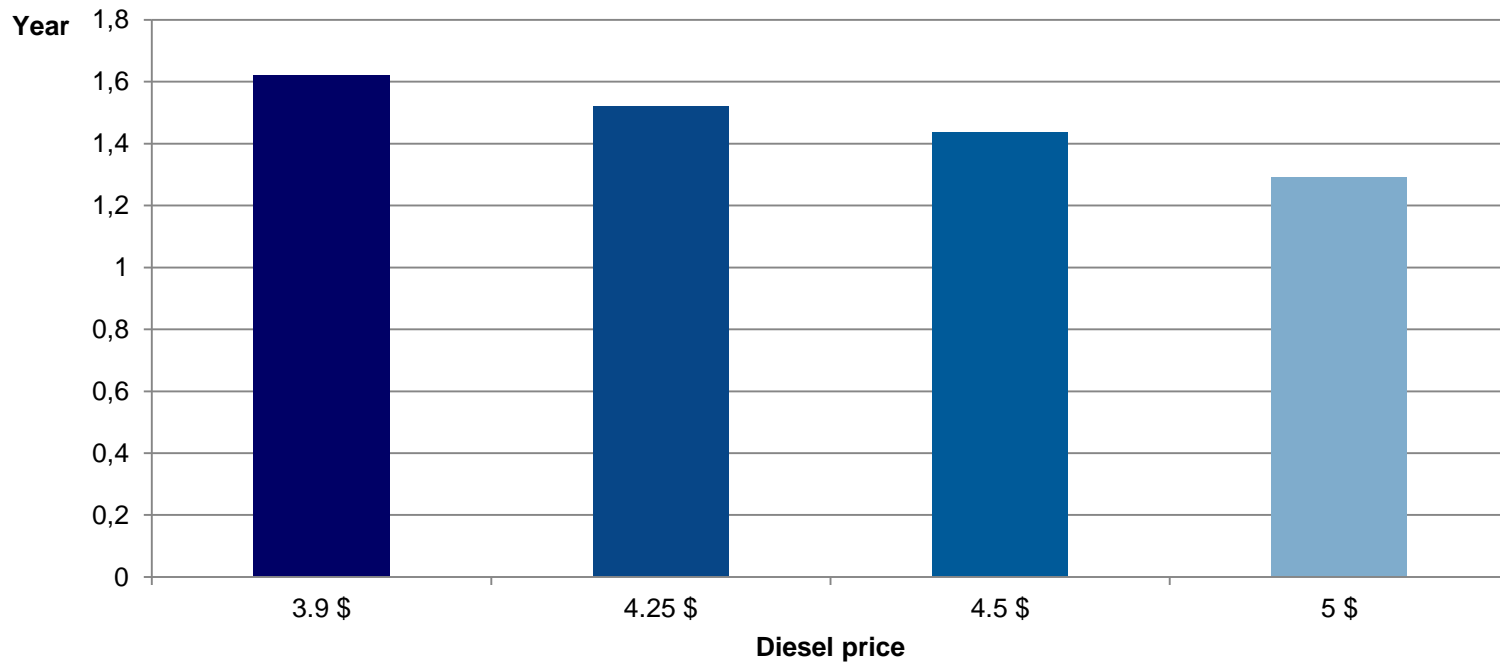


Sensitivity Analyses Fuel Price

Comparison ICE APU vs. SOFC APU

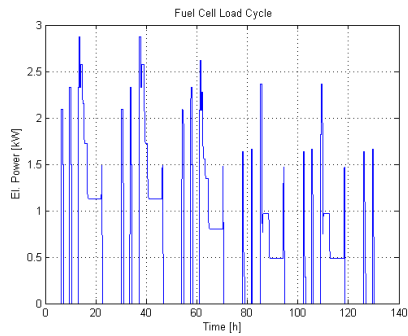
Pay back period

- 3,9 \$: 1,63 years
- 4,25 \$: 1,52 years
- 4,5 \$: 1,43 years
- 5 \$: 1,29 years

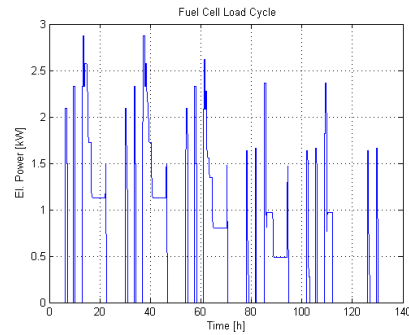


Idling Time Variation

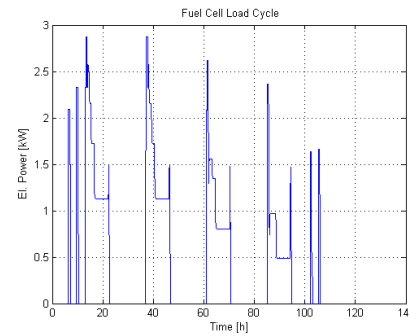
58 h



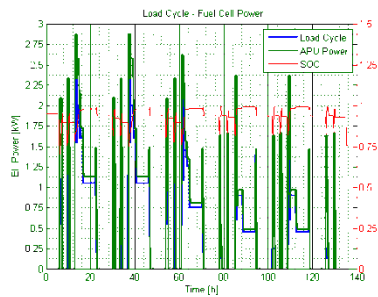
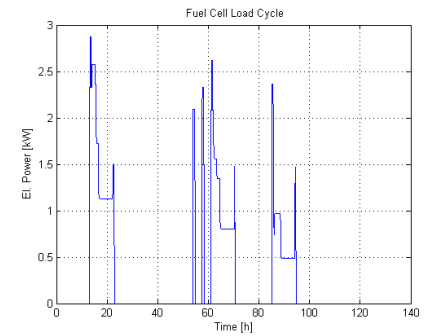
50 h



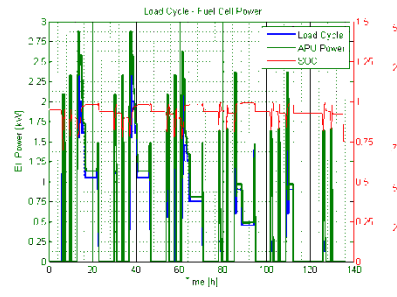
40 h



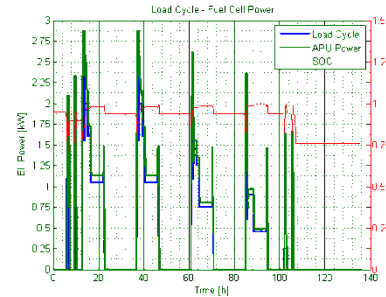
30 h



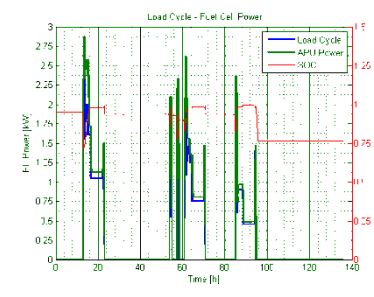
2750 h/a



2400 h/a



1900 h/a



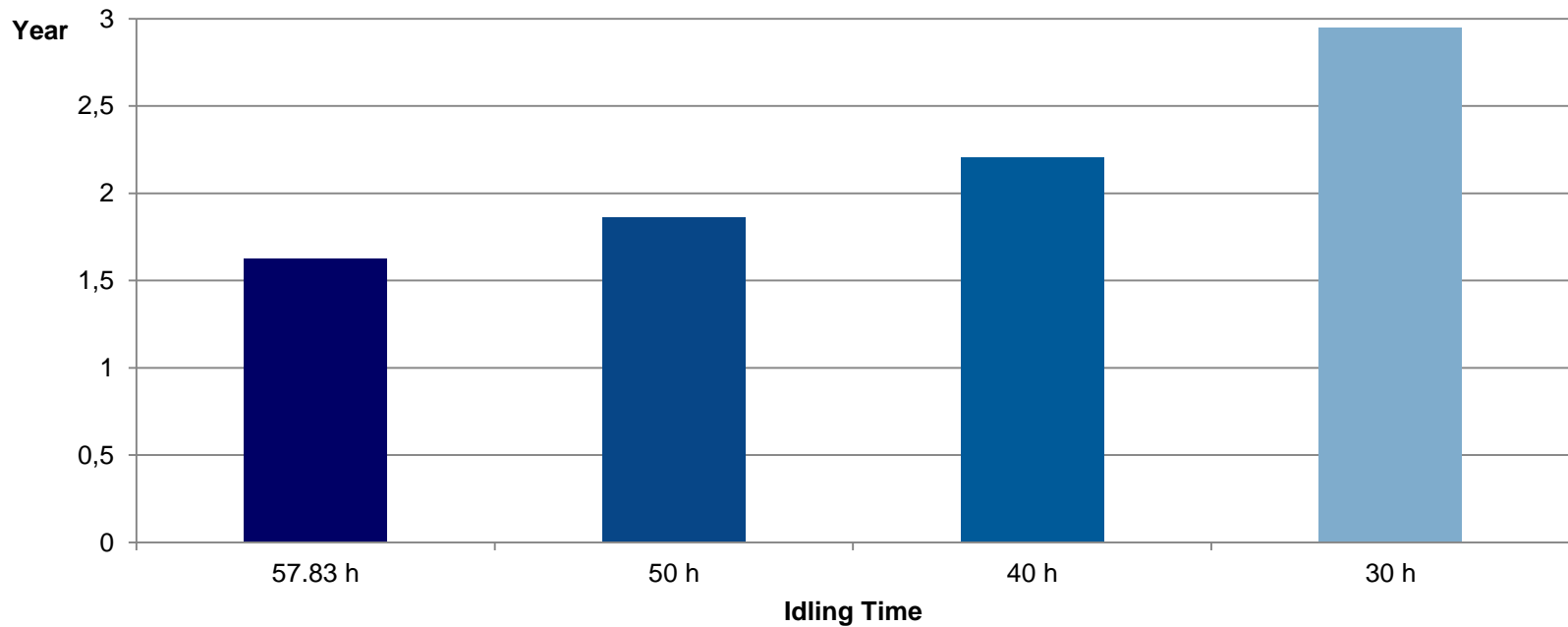
1450 h/a

Sensitivity Analyses Idling Time

Comparison **Truck Idling** vs. **SOFC APU**

Pay back period:

- 57,83 h: 1,62 years
- 50 h: 1,86 years
- 40 h: 2,20 years
- 30 h: 2,95 years

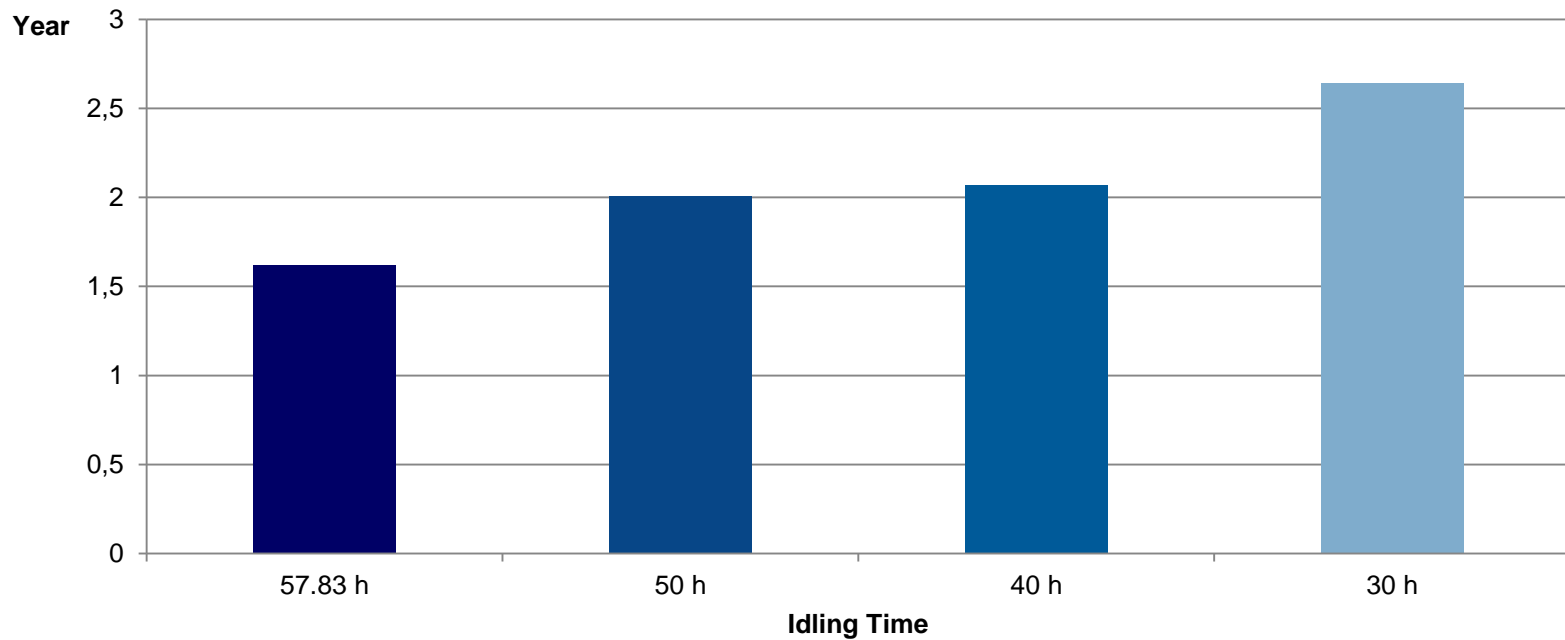


Sensitivity Analyses Idling Time

Comparison ICE APU vs. SOFC APU

Pay back period:

- 57,83 h: 1,62 years
- 50 h: 2,01 years
- 40 h: 2,07 years
- 30 h: 2,64 years

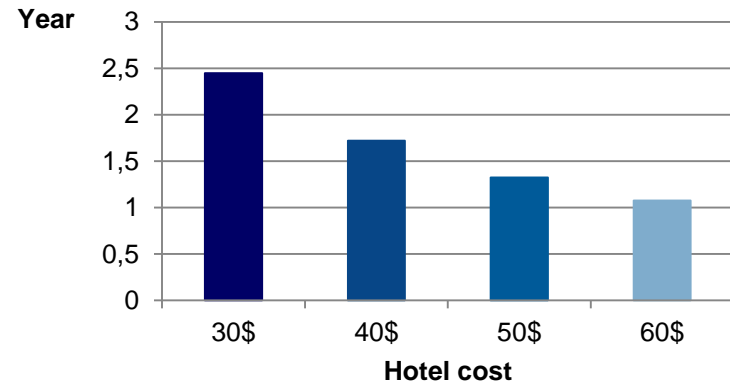


Sensitivity Analyses Hotel/Motel

Comparison **Hotel/Motel** vs. **SOFC APU**

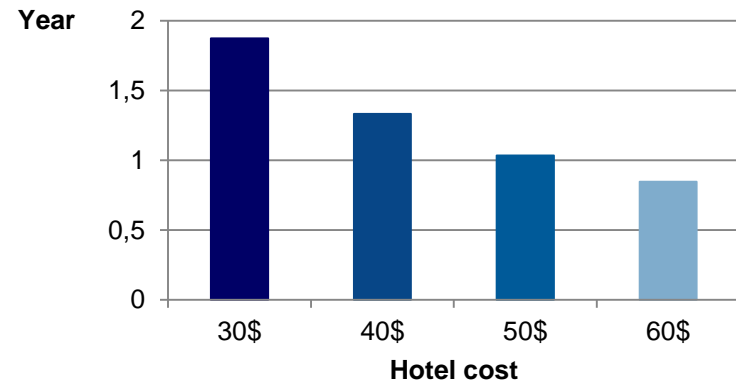
Pay back periode 4 nights:

30 \$:	2,45 years
40 \$:	1,72 years
50\$:	1,32 years
60 \$:	1,07 years



Pay back periode 5 nights:

30 \$:	1,87 years
40 \$:	1,33 years
50 \$:	1,03 years
60 \$:	0,84 years



BUSINESS CASE:

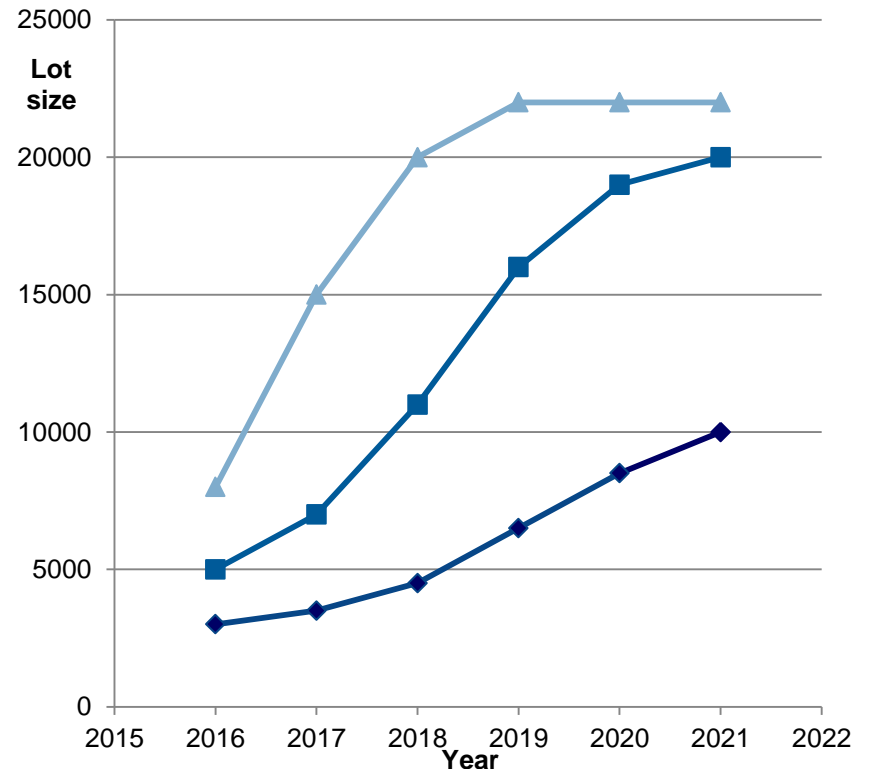
**APU OEM
(E.G. TIER 1 SUPPLIER)**

Assumptions

Invest:

- Series development, validation, certification 15.6 Mio \$
- Build up manufacturing line 2.6 Mio \$
- Sales Price: 12.000 \$
- Sales Volume (3 Scenarios):

Year	Cons.	Balanc.	Aggr.
1	3.000	5.000	8.000
2	3.500	7.000	15.000
3	4.500	11.000	20.000
4	6.500	16.000	22.000
5	8.500	19.000	22.000
6	10.000	20.000	22.000



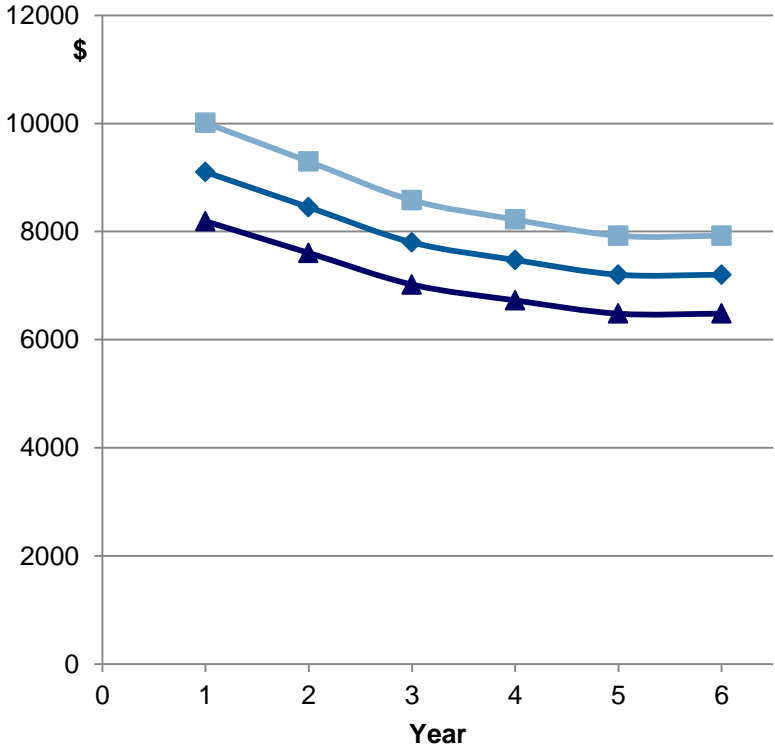


Assumptions

Production Cost incl. licence fee, sales & admin. overhead

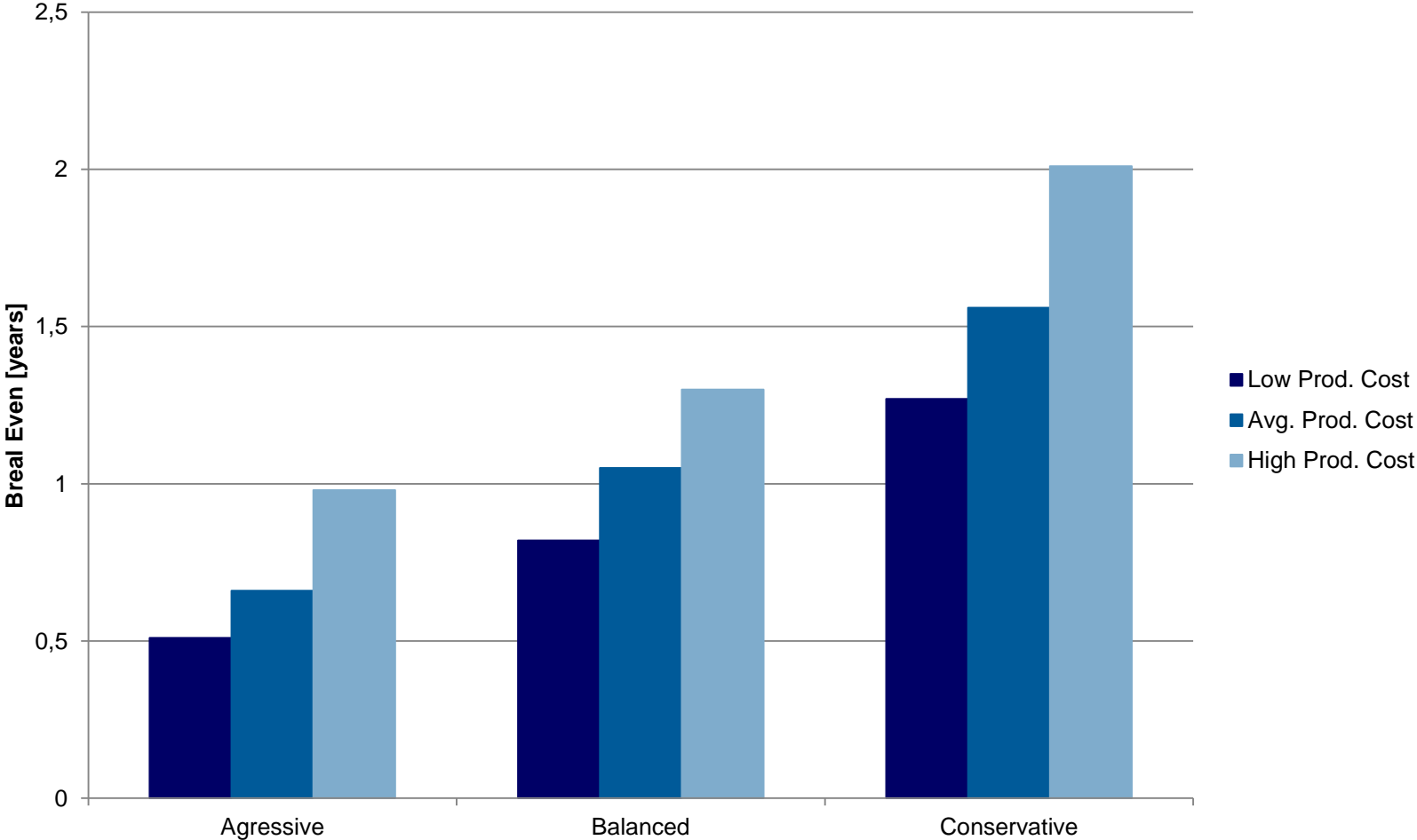
3 Scenarios:

Year	Low	Average	High
1	8.190\$	9.100\$	10.010\$
2	7.605\$	8.450\$	9.295\$
3	7.020\$	7.800\$	8.580\$
4	6.727\$	7.475\$	8.223\$
5	6.482\$	7.202\$	7.922\$
6	6.482\$	7.202\$	7.922\$



OEM Scenarios

Break Even vs. Production cost / Sales scenarios



... some Conclusions:

- Very positive business case, pay back periods between 1-2 years (under certain boundary conditions) for the end-user and the system manufacturer
- Very big interest from Truck OEMs (especially from 2 US companies), interest from potential system OEMs, but no major (financial) commitment at the moment
- Major fleet operators will decide about the success of this technology and not the truck OEMs!
- Due to expected EPA ban of idling (5min regulation) an increase of idling equipment market (volume) is expected (extension to class 5-7 vehicles)
- CO₂ credit system is a very important driver for anti-idling technology!
- already today 5min engine shut-down implementation by truck OEM creates CO₂ credits
- Business case study is without other markets like military and maritime with volumes up to 20.000-40.000 units/a (global)
- Within the last year some interest of European OEMs in APUs primary for „night logistics“

Summary

- ➔ Impressive technical progress within the last year (operation on ULSD, 30% efficiency, size, mechanical stability, vehicle integration, system test times,...)
- ➔ On the truck side next steps vehicle demonstrations to raise awareness and interest from decision makers in OEMs and big fleet operators.
- ➔ Biggest 2 hurdles for faster progress at the moment:
 - Massive supply chain problems
 - High stack costs

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