EBSF_2 TIGOT1

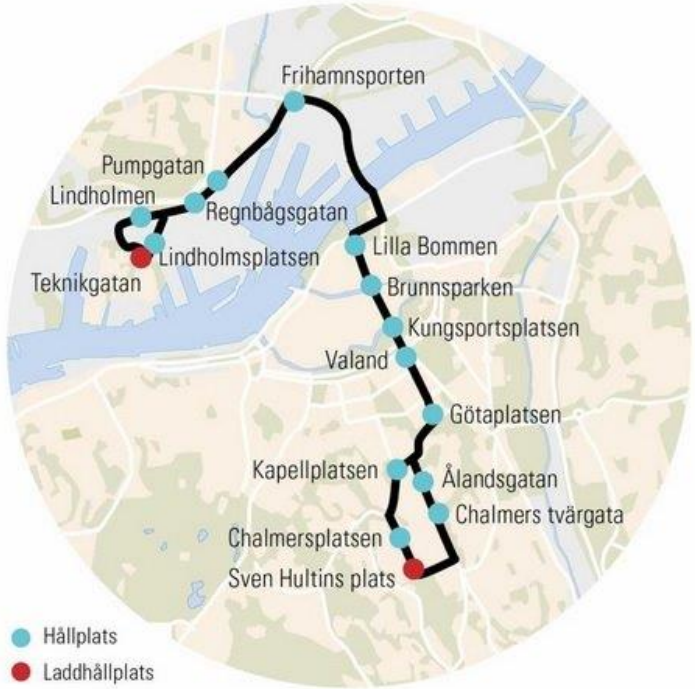
January 24, 2018

Heating system in City Buses – Background

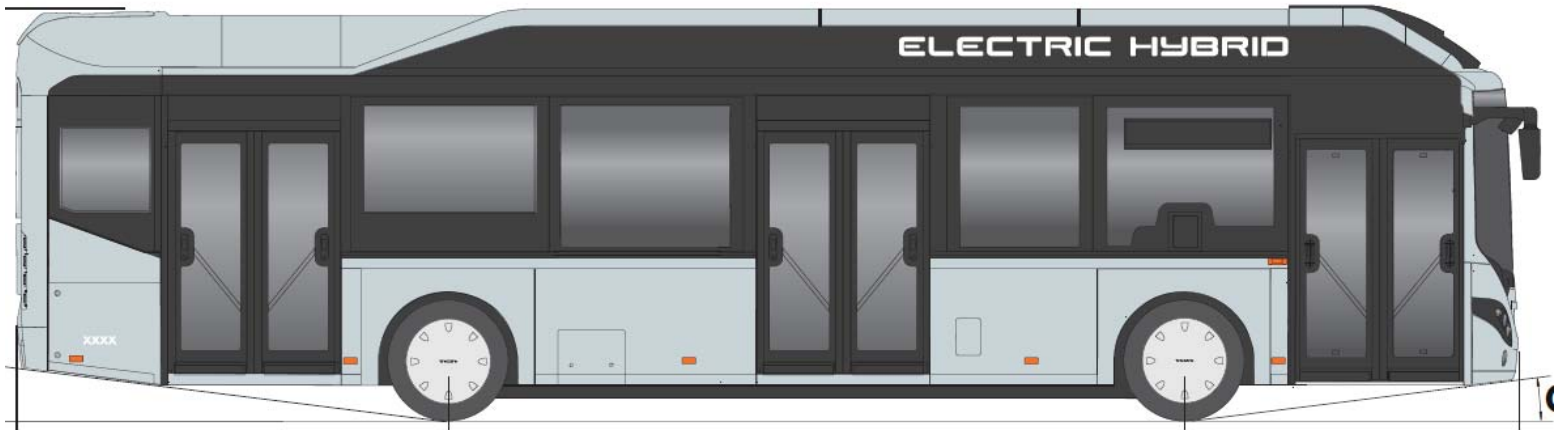
- Conventional Diesel City Bus
  - Using excess heat from engine cooling system
- Todays City Bus with high efficient Diesel Engine
  - Less excess heat available
  - > Auxiliary fuel heating system
- Todays & Future Electric City Bus
  - No or very little excess heat available
  - Introduction of zero emission zones. E.g. indoor bus stops
  - Requirement on longer driving range
  - Availability of on-board high voltage system
  - > Electric efficient heating system

VBC Project

- Target Vehicle and Operational Conditions
  - 12 m Electric City Bus with normal layout and setup
  - City bus line 55 in Gothenburg as reference operation
  - Ambient temperature 5 °C, close to average temperature in Gothenburg
- Target
  - Reduction of needed heat energy consumption by 30%
- Design
  - New efficient heating system
  - Reduction of heat losses
- Testing and Validation
  - Theoretical simulation
  - Field trial
  - Laboratory test



Bus Layout – 12 m Low Floor City Bus



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Electric Hybrid

No EBSF_2

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Electric

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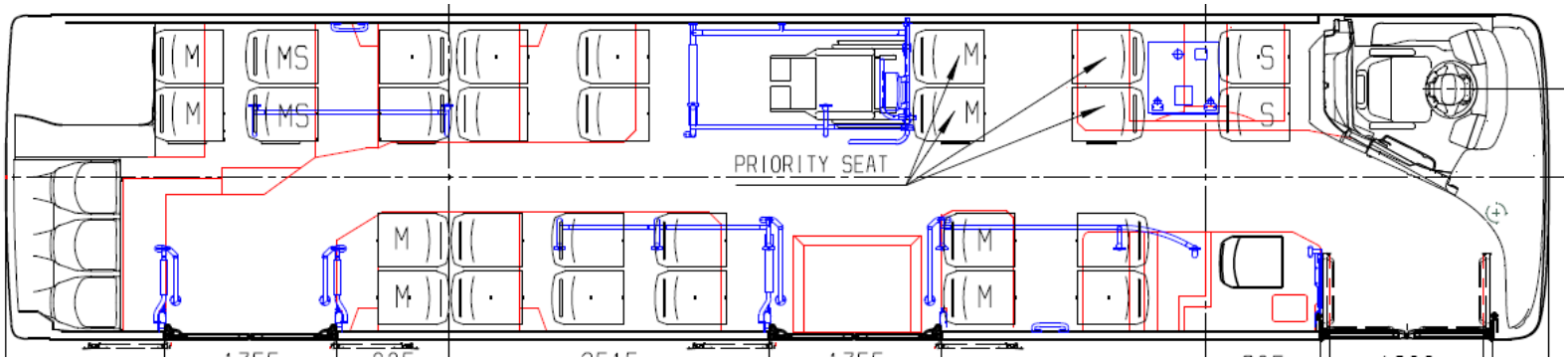
Bus Layout – Interior view



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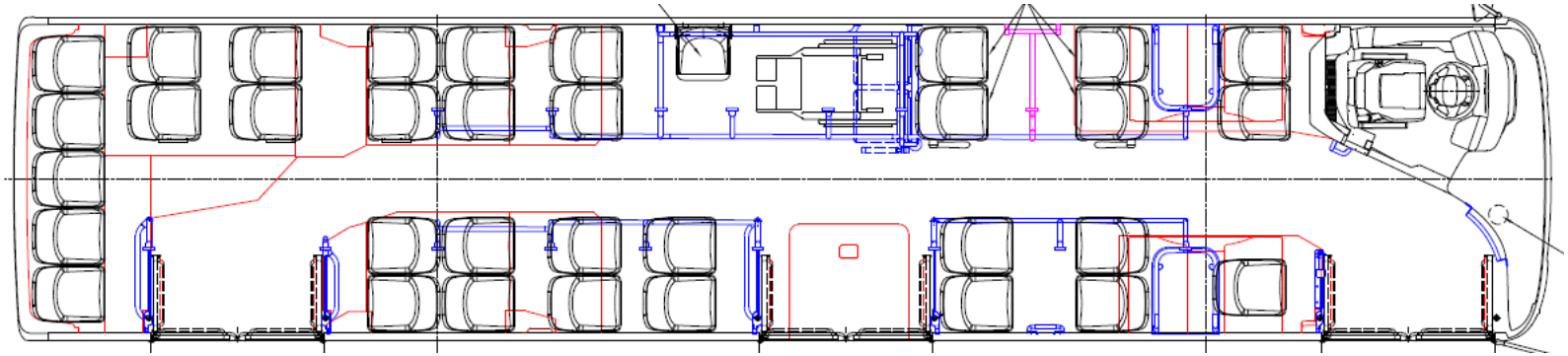

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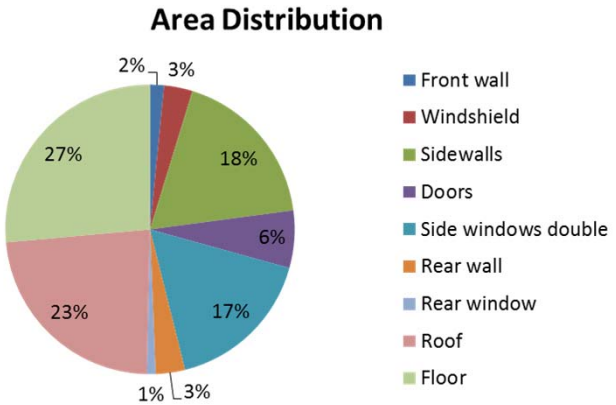
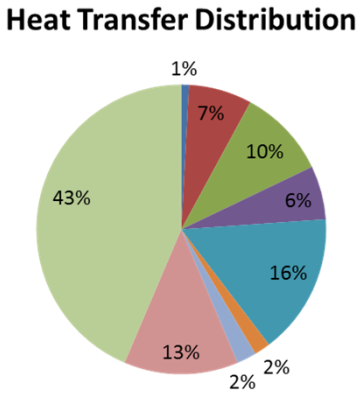
Simulation – Heat Transfer (no heat radiation)

- Target Vehicle
  - 12 m Low Floor City Bus





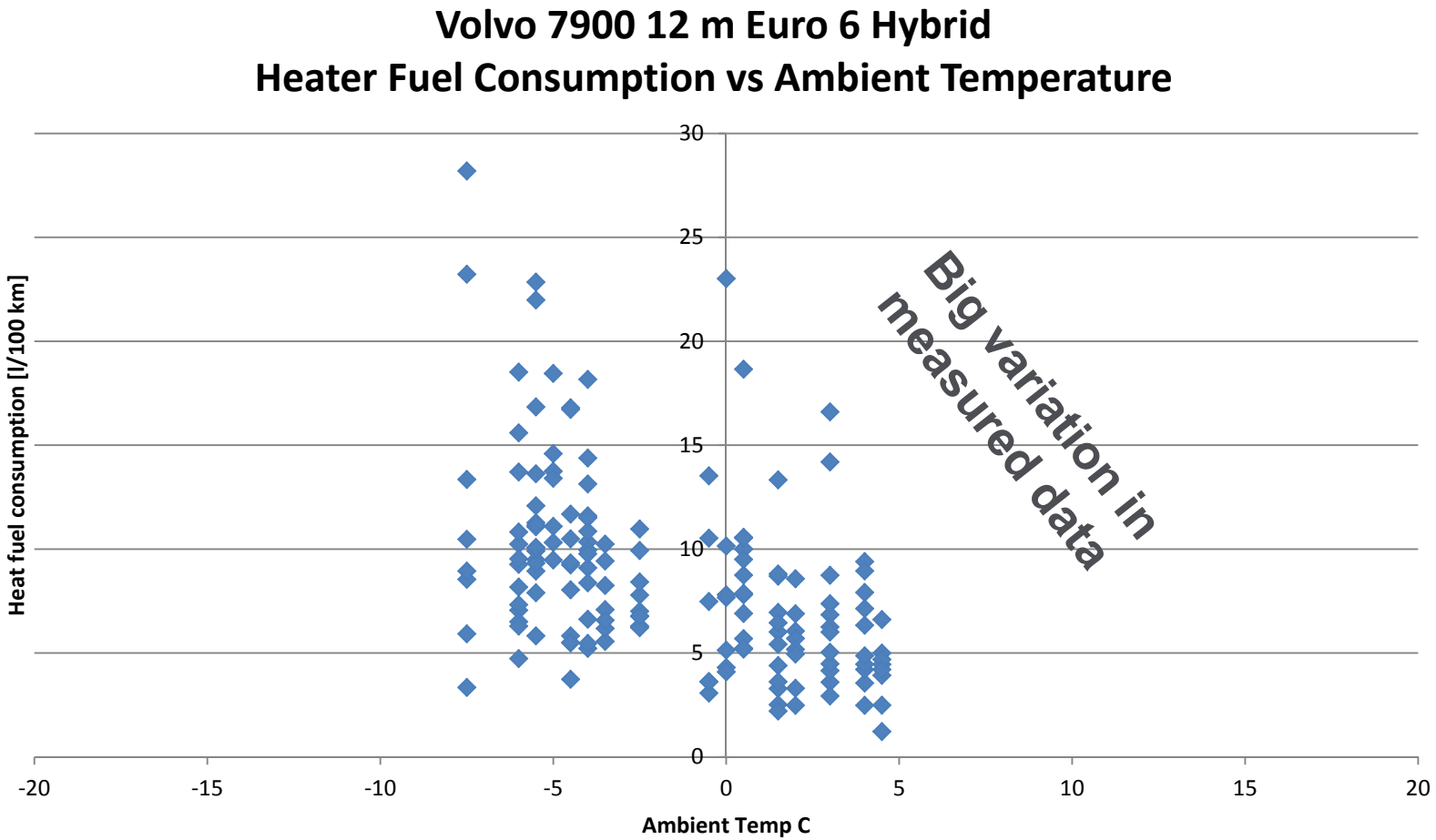
- Global Model
  - Global Heat Transfer
  - Energy balance at steady state

Field Trial

- Operation on line 55
  - Buses in operation more than one year
- Big variation of heat energy consumption from one trip to another
  - Different drivers
  - Traffic situation
  - Number of passengers
  - Number of passengers exchange
  - Different ambient climate
  - …

- More stable condition is needed in order to get reliable, comparable results

Field Trial – Example from measurement



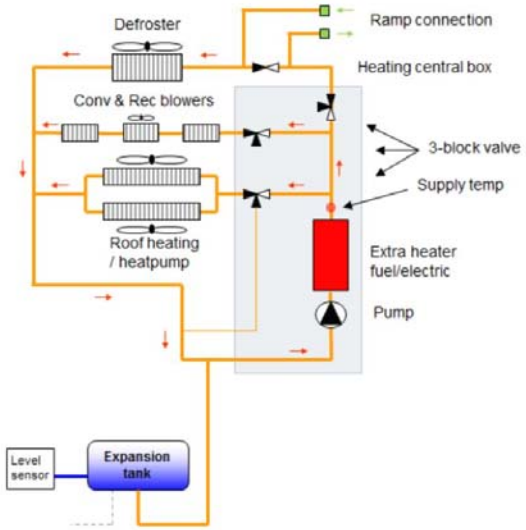
Testing in Climate Chamber for two Buses

- Controllable environment
  - Elimination of external disturbances
  - Same ambient conditions for both buses
  - Same test cycle for both buses
  - Same way of measuring for both buses
- Test procedure
  - Steady state condition at 12 °C ambient as basic starting point
  - Set temp 19 °C inside passenger compartment
  - Ambient 5 °C in chamber as in project prereq as well as average temperature in Gothenburg
  - Starting test cycle including door opening/closing sequence
  - Measuring heat power consumption during steady state condition
  - Comparing average heat power consumption for the two buses

Current vs Improved Design

	7900 Electric Hybrid Current Design	7900 Electric Improved Design	Comments
LxWxH [mm]	12000x2550x3300	12000x2550x3300	
Auxiliary heater [kW]	30 (fuel)	7 (600VDC) + 16 (fuel)	HVO
Heat pump	-	Reverse AC function	
Design	-	Improved heat insulation	
Heat management	-	Improved control system	

7900 Electric
Improved Design



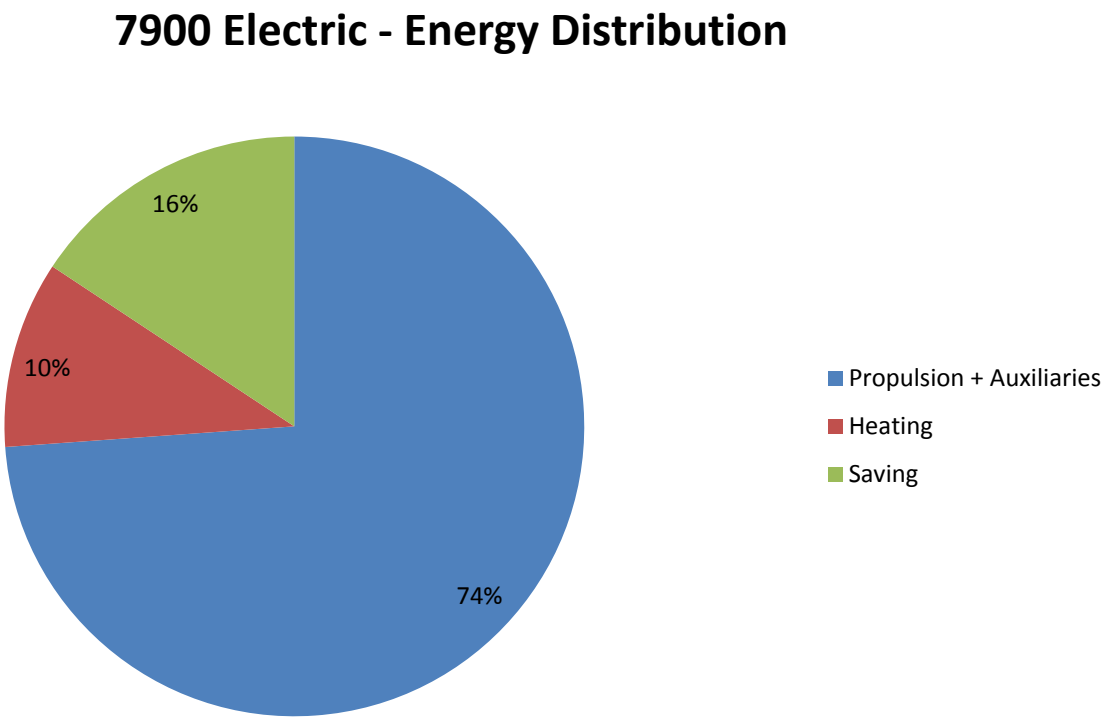
Testing in Climate Chamber – IR Camera

Testing in Climate Chamber – Results

	7900 Electric Hybrid Current Design Power [kW]	7900 Electric Improved Design Power [kW]	Comments
HVAC roof unit	0,064	0,312	
Aux heater – fuel	6,385	-	
Heat pump – 600V	-	1,853	
Aux heater – 600V	-	0,308	
Convector fans	0,02	0,02	
Defroster fan	0,02	0,02	
Coolant pump	0,128	0,128	
Total	6,617	2,641	
Reduction		-60%	

Operational Energy Saving – Bus on Line 55

- Applied results from Climate Chamber on Bus operating on Line 55
  - 5 °C ambient
  - Average speed 17 km/h
  - > Operational Energy Saving around 16%



Conclusion – Take Aways

- Heat Energy Saving exceeding target
  - High efficiency heat pump in tested environment
  - Other improvements significantly reducing heat loss
- Design / Production Phase
  - Focus on Geometry, Design and Insulation
  - Sealing; avoid heat leakage
  - Avoid heat transfer through thermal conductivity (cold bridges)
  - Choose interior material with low heat conductivity ”no cold feeling”
  - Balance fresh air intake / recirculation
- Heat Energy Consumption measurement
  - Very sensitive for operational variations
  - Use controllable, stable environment to get reliable results