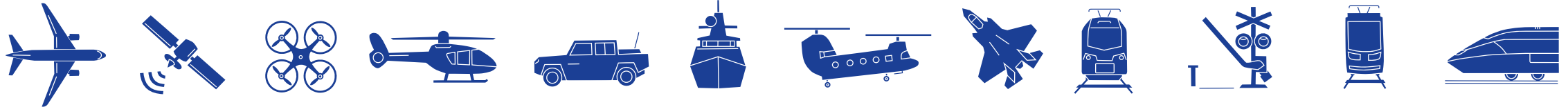


## Predictive HVAC annual energy consumption method

Development and verification

27-03-2019

Ferdinand Spek



[www.adse.eu](http://www.adse.eu)

ENGINEERING | DESIGN | CERTIFICATION

PROCESS | ORGANISATION | CONSULTANCY



EXPERTISE

NEXT GENERATION TRANSPORTATION SYSTEMS



IMPROVEMENTS

SOLUTIONS

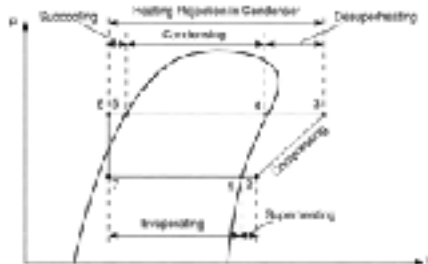


INNOVATIONS



- Background
- EcoTram project
- Closing the loop
  - Why is it important?
  - Who can benefit?
- Calculation model overview
- Outlook

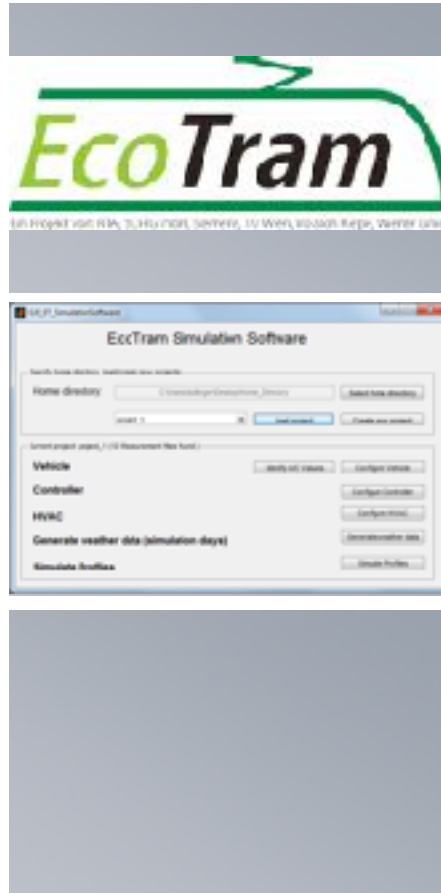




- Total Energy use is very important parameter
  - LCC
  - CO<sub>2</sub> emissions
- But total HVAC energy use is not dependent upon 1 party
  - Integrator – Vehicle boundary conditions
  - HVAC supplier – System
  - Operator – Usage
  - Weather – Environmental conditions
- Determining HVAC energy use requires a close collaboration between all parties involved



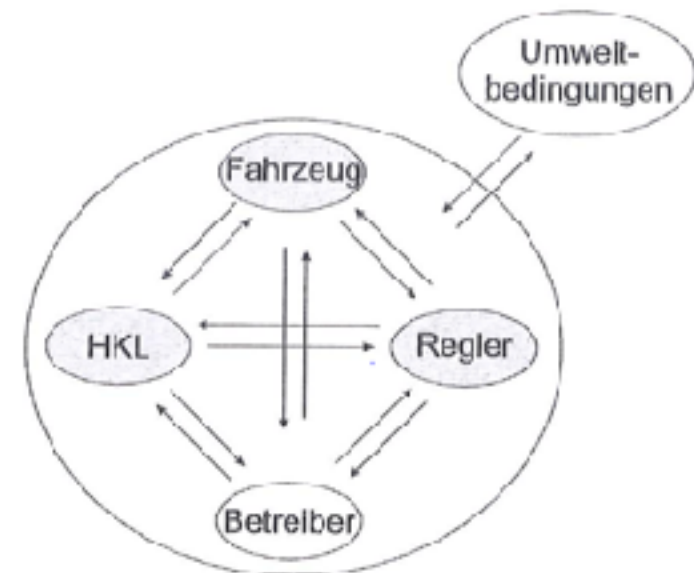
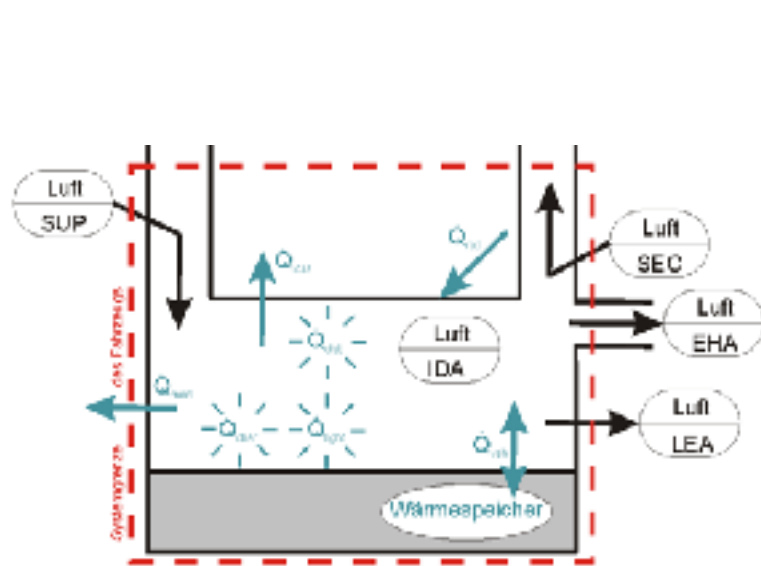
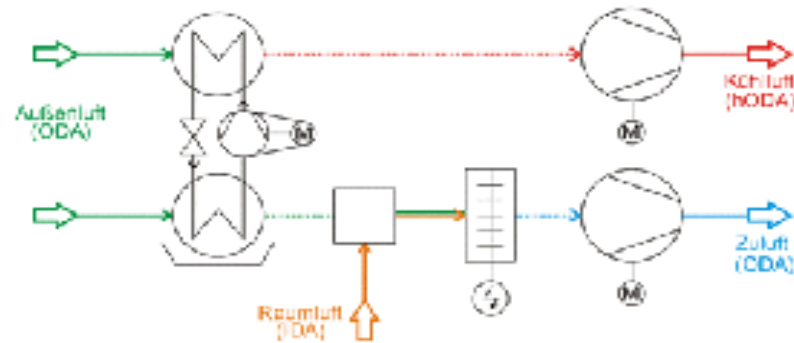
- EcoTram research project 2010-2014
  - RTA
  - Wiener Linien
  - Siemens
  - Vossloh Kiepe
  - SCHIG mbh
  - TU Wien
  
- 2 parts:
  - Hardware testing – improvements, climatic chamber and in-service
  - Simulation of HVAC energy usage



Simulation objectives:

- Determination of the energy consumption from a HVAC system on a tram (specialized for the Vienna ULF)
- Further investigation/ simulation of the thermal comfort in the tram out of measured data from climatic tests in the CWT
- Estimation of influences due to different environmental conditions
  - Variation of outside air temperature
  - Relative humidity
  - Solar radiation
  - Passenger loads

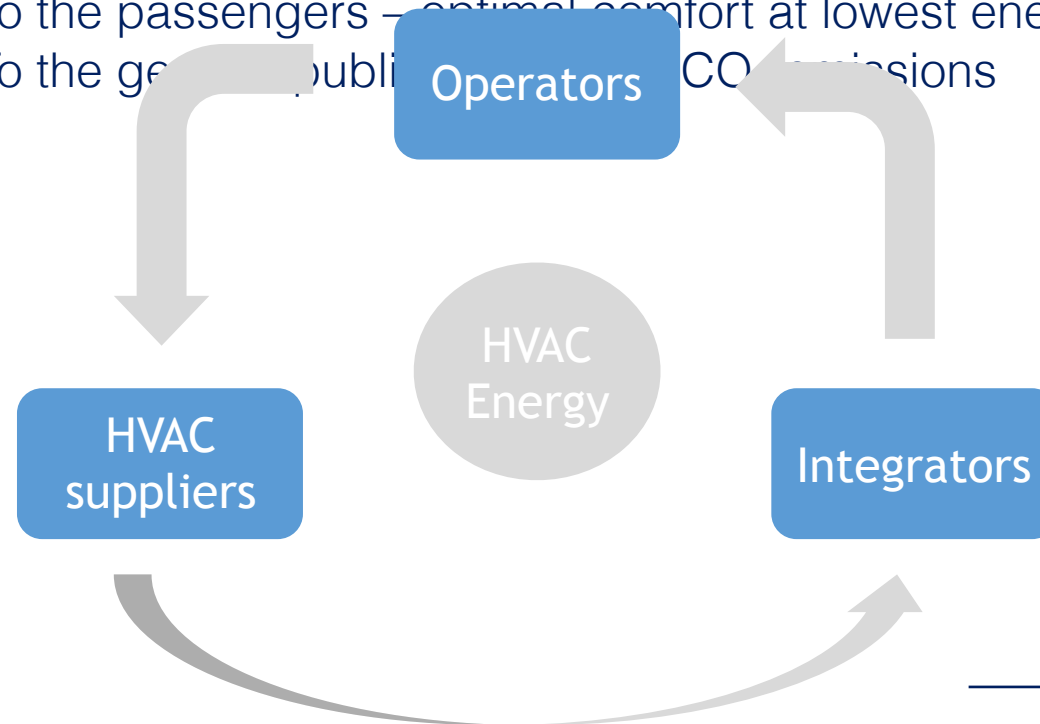




## Closing the loop

Closing the loop on HVAC energy usage is important

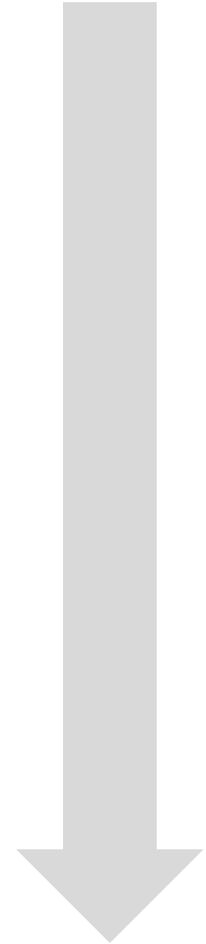
- To the operator – reducing energy usage with an optimal system
- To the Integrator – providing a cost effective solution
- To the HVAC supplier – providing an efficient and optimized system
- To the passengers – optimal comfort at lowest energy use
- To the general public – reduced CO<sub>2</sub> emissions



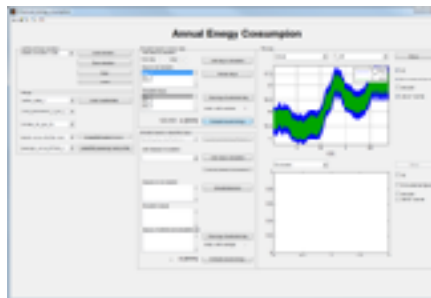
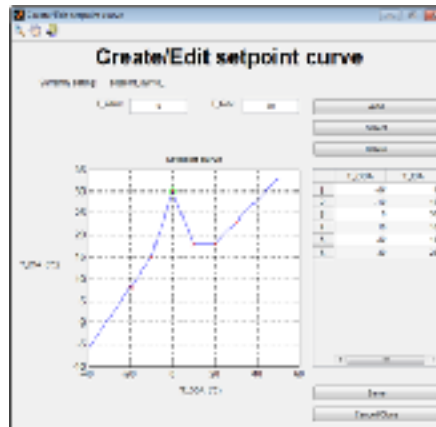
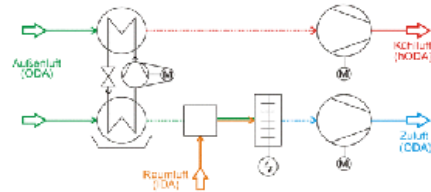


Using the model is possible throughout the entire lifecycle

- Requirements phase
  - Requirements trade-off
- Bidding phase
  - Predicting energy use for LCC
- Design phase
  - Trade-off studies for different design options
  - Design optimization
- Test phase
  - Predicting test results
  - Using test results to validate model
  - Predict conditions that are not tested
- Operational phase
  - Calculate changes in operational scenario's or conditions
  - Verify model against measured in-service data
- Upgrade
  - Calculate energy usage with rolling stock and/or HVAC upgrade



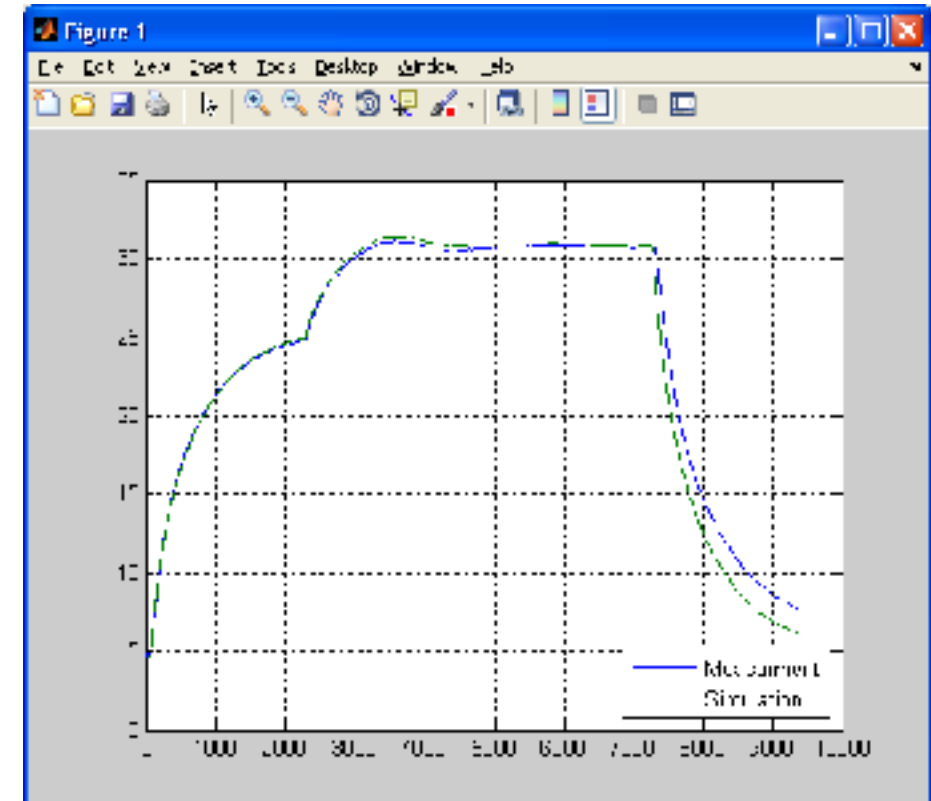
## Calculation model overview



- Step 1: Vehicle definition
  - Either based on data or on CWT test
- Step 2: HVAC data definition
- Step 3: HVAC control definition
- Step 4: Environmental definition
- Step 5: Creation of setpoint curves and passenger loads for the annual energy consumption
- Step 6: Calculation of annual energy consumption
  - Simulation of single days or defined classes from the weather classification

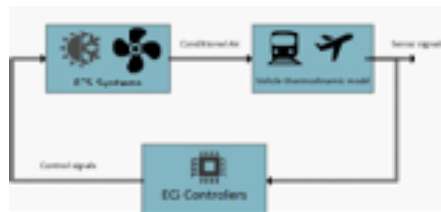
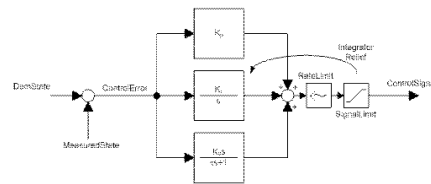
## Calculation model overview: verification

- Preliminary model verification results are positive on tram.
- Model verification is currently expanded to high speed trains to cover full range of rolling stock.
- Model verification depends on vehicle and HVAC system architecture.
- Using results from climatic testing, simulation results can be verified
- Real life operating condition can be predicted using the verified model.



- Based on vehicle and HVAC data the model calculates
  - Total yearly HVAC energy usage
  - Specific daily profiles; interior conditions and HVAC energy usage
- The model supports
  - Design
  - Test
  - Operation
- What-if scenario's
- Daily profiles like in EN13129 or operator specific

# Outlook: HVAC Trends



- 'Low hanging fruit' has been picked
  - Fresh air ventilation based on passenger count
  - Heat-pump application
  - Energy efficient fans
  
- Now more effort is needed
  - Optimize control strategy
  - Optimize unit hardware integration
  - Continuous modulation of heating and cooling power
  
- This requires an upfront cost (money and time) and integration effort
  - Use of tools is required
  - (More) Testing is needed to validate models and allow extrapolation

## Closing the loop

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- Using an integrated model to calculate HVAC energy use closes the loop
  - System supplier → OEM → Operator
  - Design → Test → Operation
  
- Potential benefits
  - Operators – reduce CO<sub>2</sub> emissions
  - Industry – to provide next gen efficient HVAC technology
  
- Current HVAC trends necessitate the need for the use of models
  - Integrated models are preferred
  - Support the full life cycle
  
- Development of models is well underway
  - Verification must be included in development
  - First results are promising

## Contact details

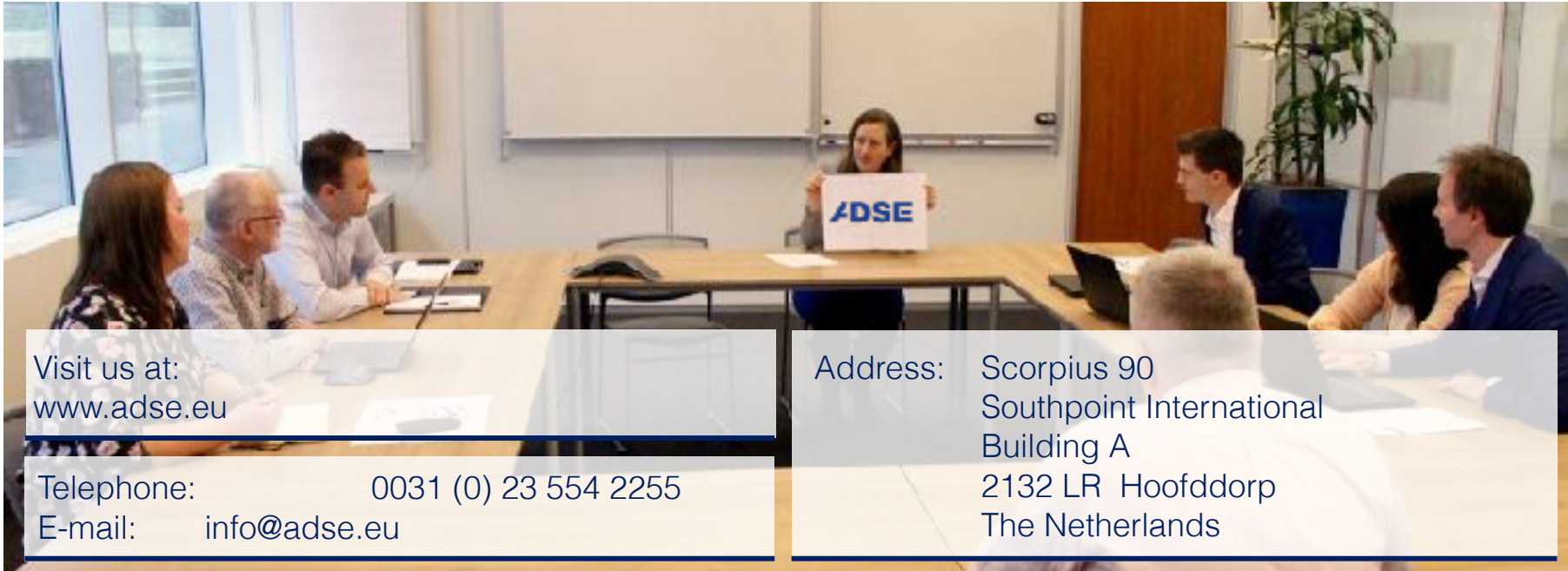
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