# Improved winter range in e-vehicles by anti-fog window coating

## ECS Simulation Conference 2021

Dr. T. Schmidt, Owner, GXC Coatings

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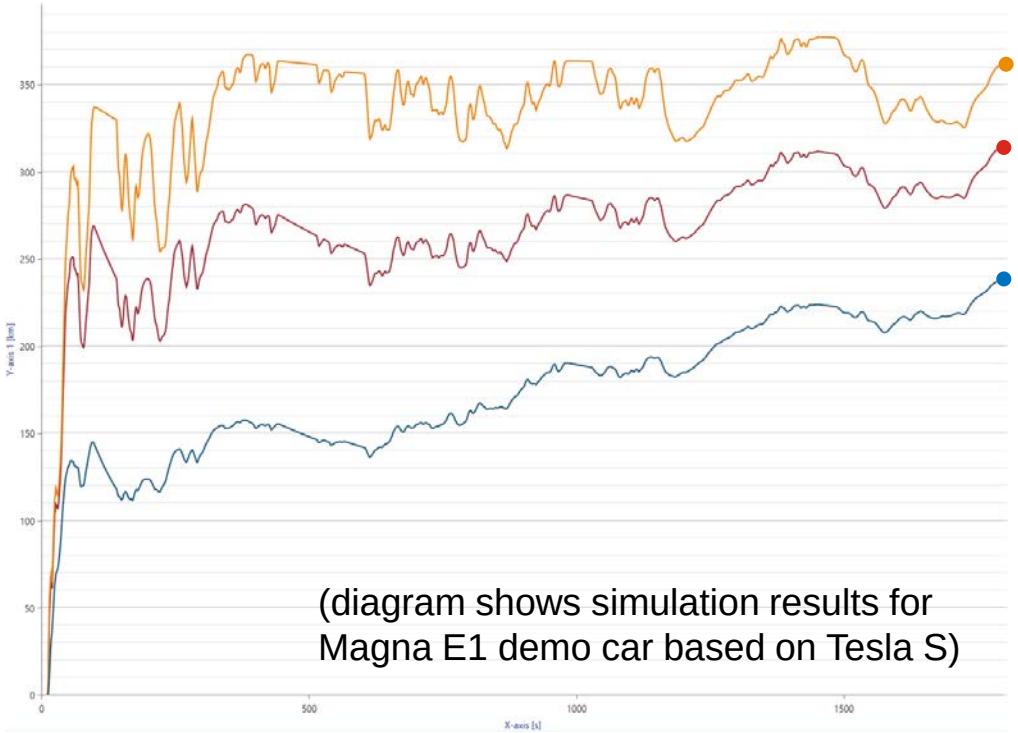
# Introduction – Ambient Conditions and EV Range

Range of an Electric Vehicle for the WLTC in different climate conditions:

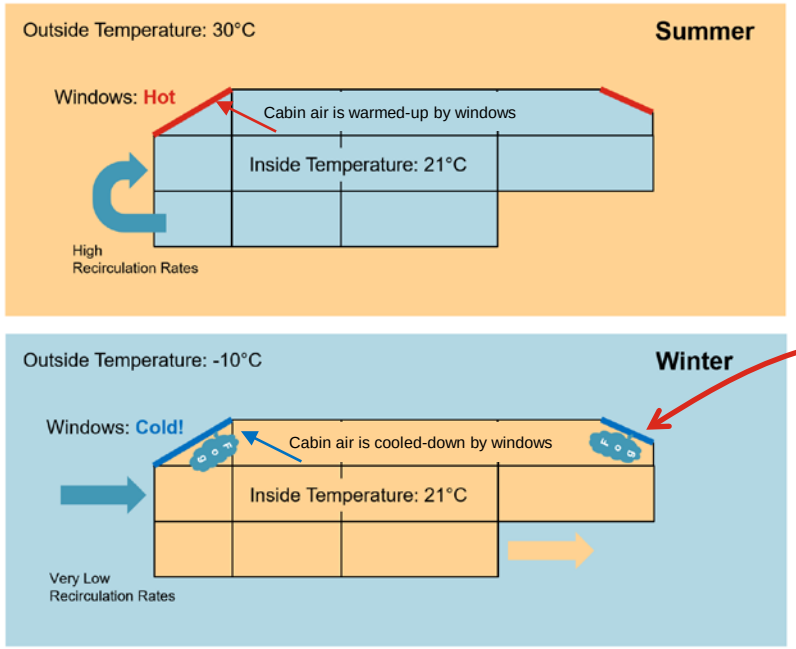


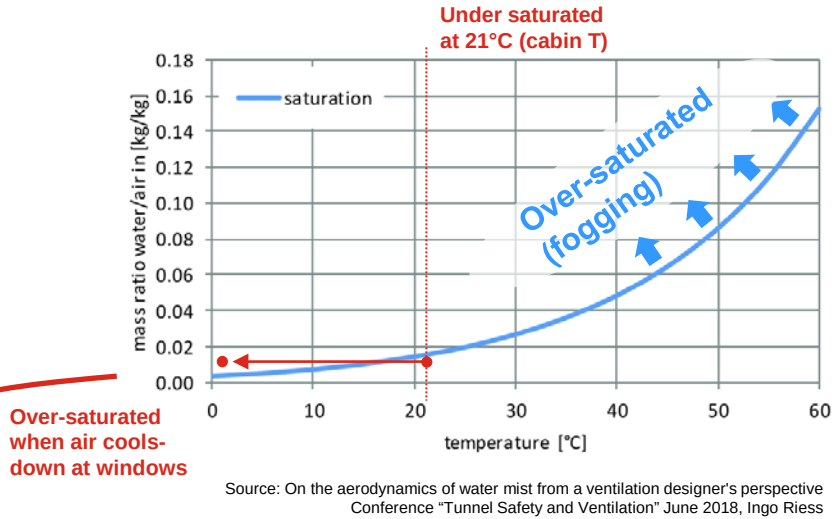

**Base: Spring, 21°C Ambient T**
**Summer: 40°C Ambient T**
**Winter: -10°C Ambient T**

- HVAC energy consumption has a significant impact on EV range
- Typical published values **summer** **-10% to -30% range**
- Typical published values **winter** **-30% to -50% range**

Author: C. Rathberger, ECS

# Why Winter Conditions are Critical - Window Fogging



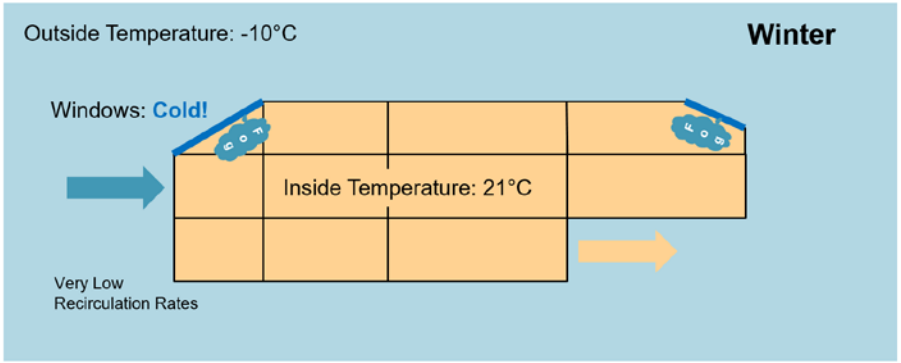

Source: On the aerodynamics of water mist from a ventilation designer's perspective
Conference "Tunnel Safety and Ventilation" June 2018, Ingo Riess

In winter conditions passenger cabins are usually run in **fresh air mode**

Otherwise humidity emitted by passengers can quickly lead to window fogging

Author: C. Rathberger, ECS

# Air Recirculation and HVAC Energy Consumption - A Simple Calculation Example




Typical vent temperature for heating:
55°C

Example air mass flow rate:
200kg/h = 0.056kg/s

Outside temperature:
-10°C

Cabin temperature:
21°C

Air specific thermal capacity:
~1000J/kg/K

A quick calculation shows that a lot of energy could be saved by air recirculation (warm-up of cabin air to duct temperature instead of cold ambient air!)

$P = mp * cp * \Delta T$

$P_{PTC\_fresh}$ = 0.056*1000*[55-**(-10)**] = 3640W

$P_{PTC\_recirc}$ = 0.056*1000*(55-**21**) = 1904W

Cabin T!

↓ -48% required heating power (steady state)!

→ **But how to solve the problem of window fogging?**

Author: C. Rathberger, ECS

# An Alternative Solution for the Fogging Issue - Proposed Idea by GXC Coatings

- Idea: What if condensation at the windows is not *prevented, but changed* from
  - **Droplets** (fogging) to
  - **Film** (fully transparent)
- A coating developed by company GXC coatings does exactly this…
- So de-humidification takes place in a controlled way that still allows very high air recirculation rates!

**Front with GXC-Coating:** Film, but no fog!

**Side-window w/o coating:** Full fogging!

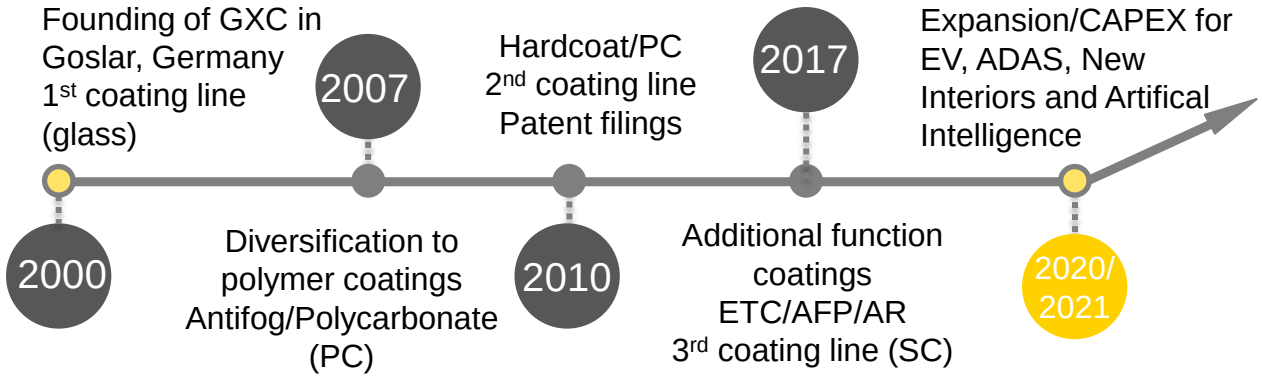
| | |
|---|---|
| Climate Chamber: | -3°C |
| # of Passengers: | 4 |
| Recirculation: | 100% |
| Picture taken after: | 1h |

Author: C. Rathberger, ECS

# GXC Coatings

A Short Overview…

# GXC BACKGROUND AND OUTLOOK




Author: T. Schmidt, GXC

# GXC COMPETENCIES

## DEVELOPMENT

- International patents
- 3 chemical laboratories
- Antifog, hardcoat, hybrids and additional functions like anti reflective, easy to clean, etc.
- Protected application technologies (2in1)

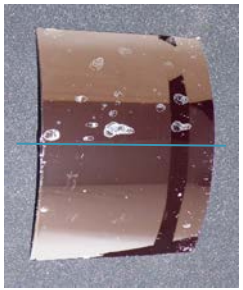
## MANUFACTURING ( COATING MATERIAL)

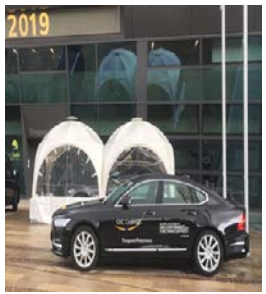
- Manufacturing of liquid coating materials
- Capacitites several tons/a
- Contract research and joint development agreements (JDA) with international partners

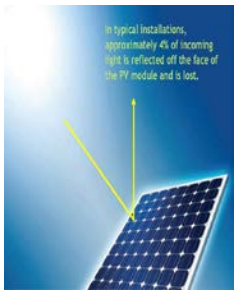
## APPLICATION (COATING SERVICES)

- 3 automatic coating lines
- PST- Precision Spray Technology
- Homogenous coating layers
- Masking is possible
- Clean Room Claas 4-5
- Automotive Standards

# GXC FUNCTIONAL COATINGS






| ANTI FOG | HARDCOAT (INTERIOR) | HARDCOAT (EXTERIOR) | ANTI DIRT | ANTI REFLECTIVE |
|---|---|---|---|---|
| • Automotive lighting<br>• Autonomous driving<br>• Instruments, cameras<br>• Industrial sensors<br>• Helmet visors | • Driver monitoring<br>• HMI touch elements<br>• Optical sensors<br>• Mirrors, ophtalmics<br>• Helmet visors | • LIDAR covers<br>• Touch instruments<br>• Cameras, lighting<br>• Traffic surveillance<br>• Architecture | • Auto exterior parts<br>• Autonomous driving<br>• Instruments, displays<br>• Ext sensors, lighting<br>• Reflectors | • PC-IR covers<br>• Glass IR covers<br>• Optical lenses<br>• Medtech<br>• Photovotaics |



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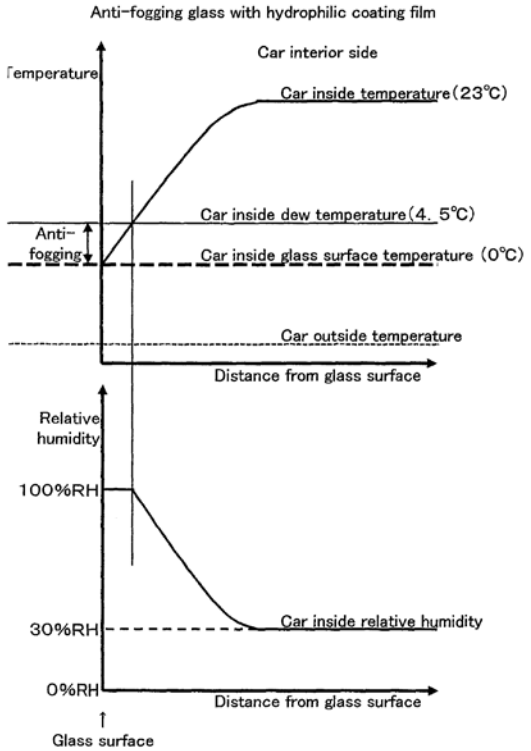
# ALLOWING CONDENSATION BUT AVOIDING ITS VISIBILITY



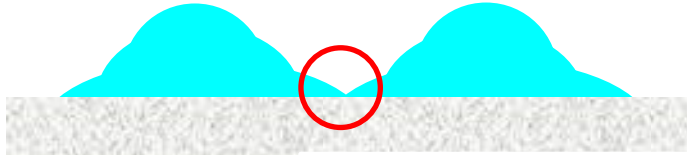

Antifog coating reduces energy consumption by the amount needed to reduce dew point to outside glazing temperature as well as to clear condensation. Ref.: EP2123448A1

# TECHNICAL CONCEPT– HYDROPHILIC ANTIFOG COATINGS

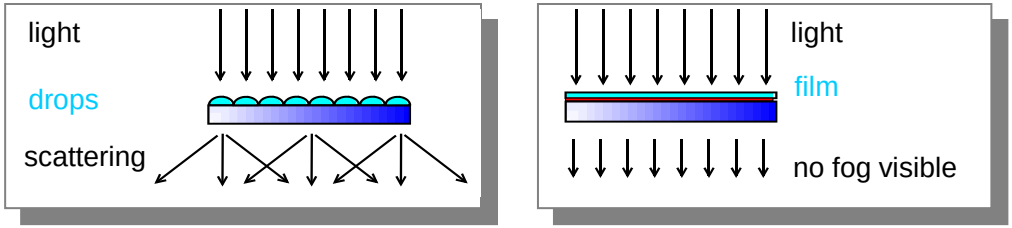
GXC Coatings

Avoiding visible condensation

Spreading of water droplets by hydrophilic coatings



No scattering of light




Uncoated glazing

Antifog coated glazing



Author: T. Schmidt, GXC

# GXC GEN 1 TECHNOLOGY – DRIVING TEST

PERMANENT ANTIFOG:
REALITY DRIVING TEST

Condensation was forced by driving in recycle air mode for 2 min at outside temp 6°C, 3 persons in cabin, inside temperature 23°C.

# Identification of Potential Benefits

## Impact of Recirculation on Winter Range
## KULI Simulation Benefit Study for WLTC @ -10°C

Author: C. Rathberger, ECS

# Investigated Vehicle / Thermal Simulation Model

- Magna E1 Demonstrator Car
  - Based on Tesla S
- High Performance EV
  - Peak power 420kW
- Vehicle Class
  - Full size luxury car (F)
- Complete Thermal Simulation Model in KULI
  - Also capable of predicting vehicle range for given drive cycles
  - Will be used to compare range for different cabin air recirculation rates…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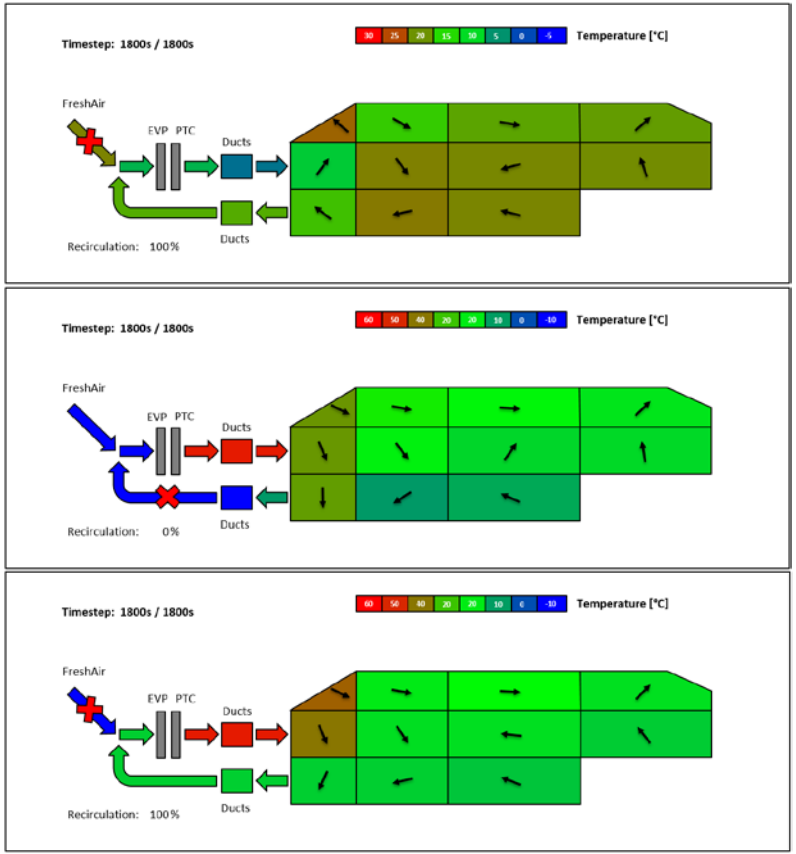
# Simulated Conditions




**Baseline: Ambient T = 21°C**
Solar radiation 600W/m²
100% recirculation

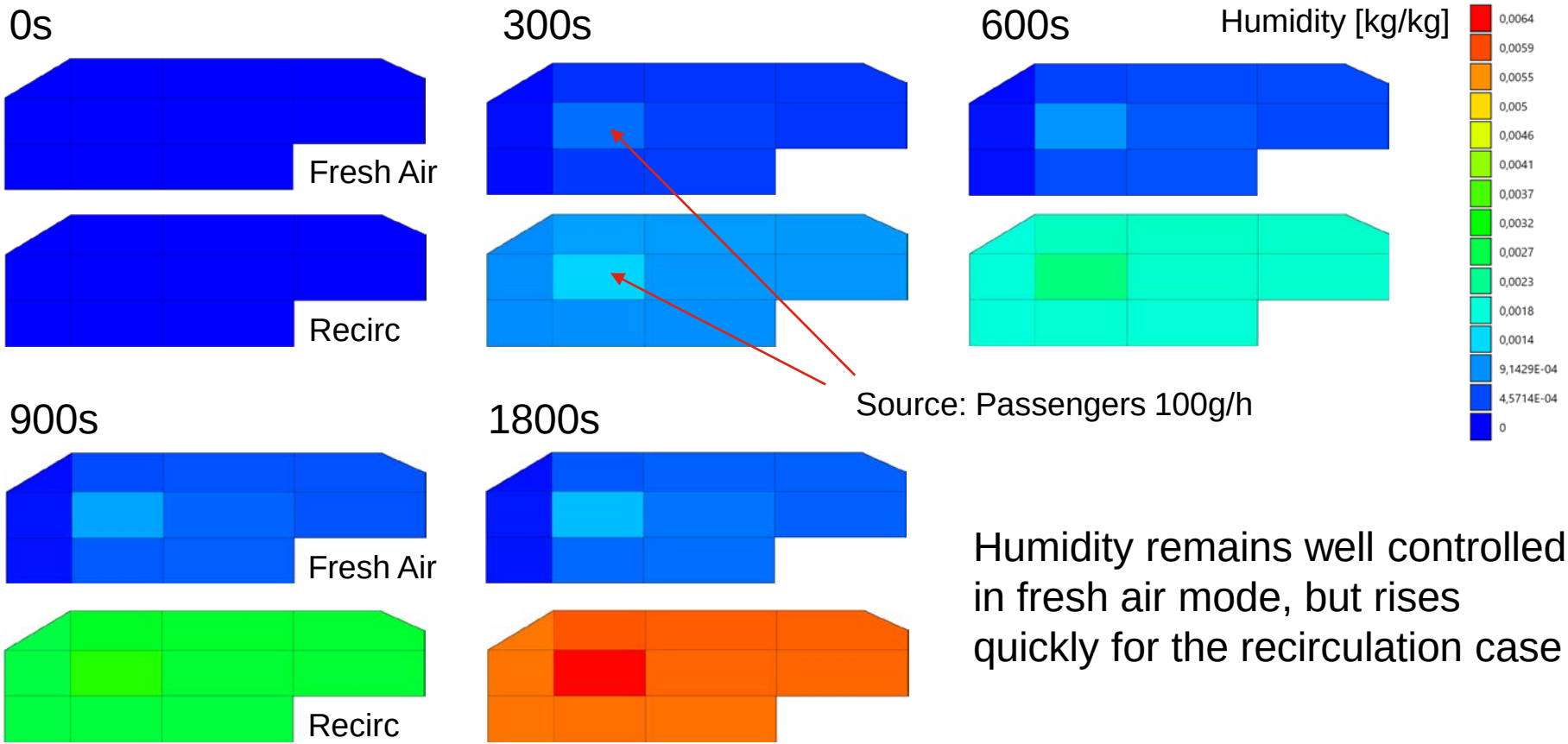
**Baseline Winter: Ambient T = -10°C**
Solar radiation 0W/m²
0% recirculation

**GXC Case Winter: Ambient T = -10°C**
Solar radiation 0W/m²
100% recirculation

➧ Range Benefit?

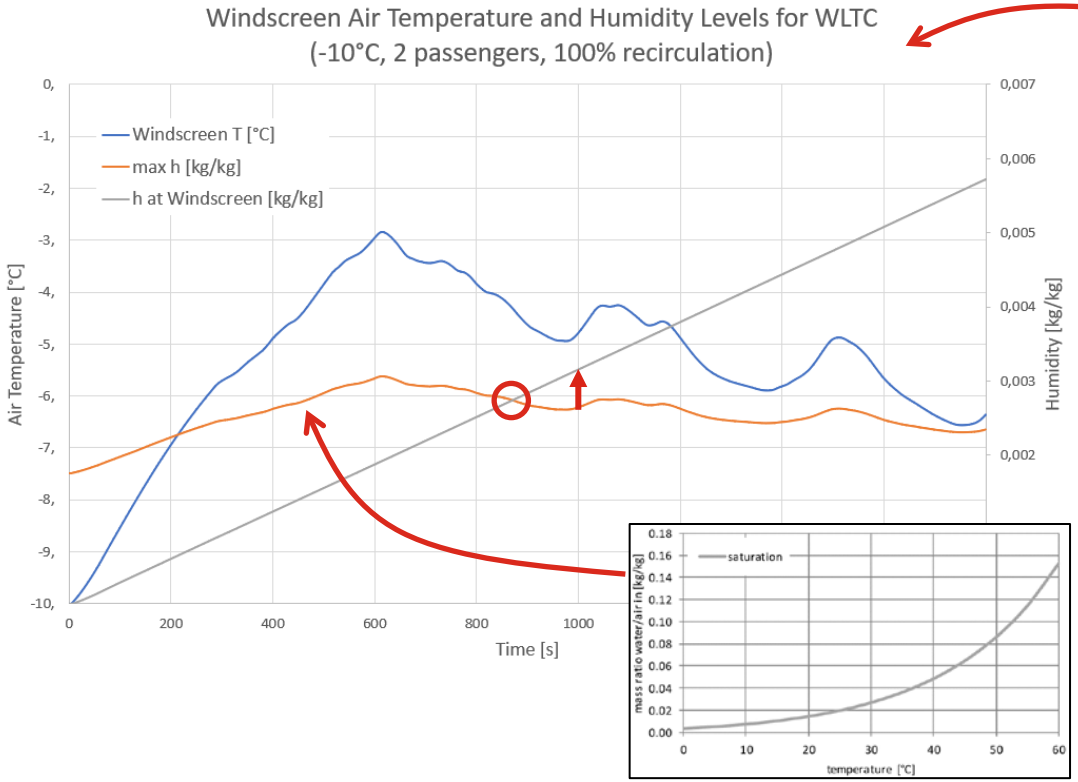
Author: C. Rathberger, ECS

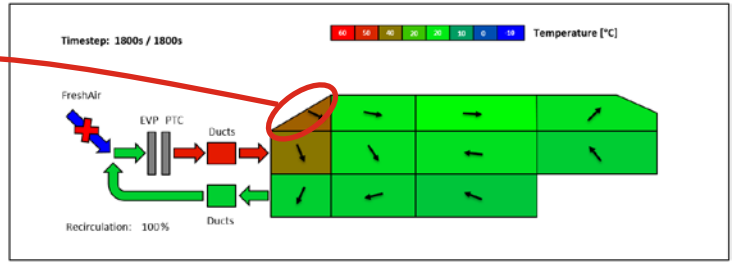
# Humidity Distribution in Passenger Cabin




Humidity remains well controlled in fresh air mode, but rises quickly for the recirculation case

# How Long Until Condensation Occurs?




For warm-up case at -10°C ambient T, simulation predicts condensation after around 14min…

This is actually intended, if we use the GXC-coated windscreen actively for de-humidization…

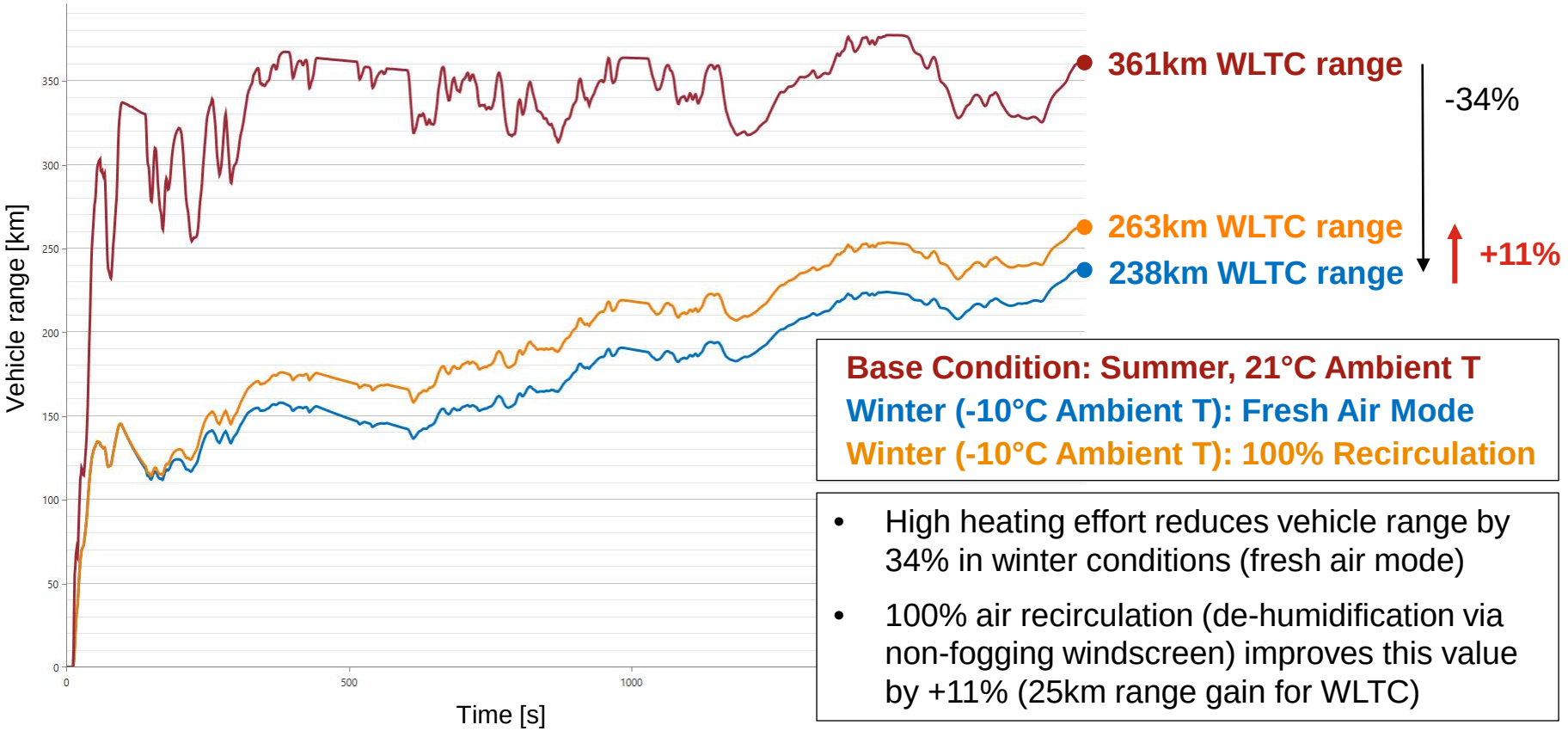
In the subsequent investigation the focus is put on the **energy balance** instead…

# Further Boundary Conditions of the Following Simulations

- Simulations were done for dry air and without passengers in the vehicle
  - Main question was the ***energy saving potential***
  - An explicit model for air-dehumidification and condensate flow was not the primary focus in this investigation (we already know that de-humidification works based on GXC testing)
  - Humidity can be considered in subsequent investigations but will not change the general results much!

- The implemented HVAC controls are generic and simplified controls, but good enough to reproduce the general vehicle behavior
  - Again no impact on general findings expected.

# Positive Impact of Cabin Air Recirculation on Vehicle Range in Winter Conditions (WLTC)




**Base Condition: Summer, 21°C Ambient T**
**Winter (-10°C Ambient T): Fresh Air Mode**
**Winter (-10°C Ambient T): 100% Recirculation**

- High heating effort reduces vehicle range by 34% in winter conditions (fresh air mode)
- 100% air recirculation (de-humidification via non-fogging windscreen) improves this value by +11% (25km range gain for WLTC)

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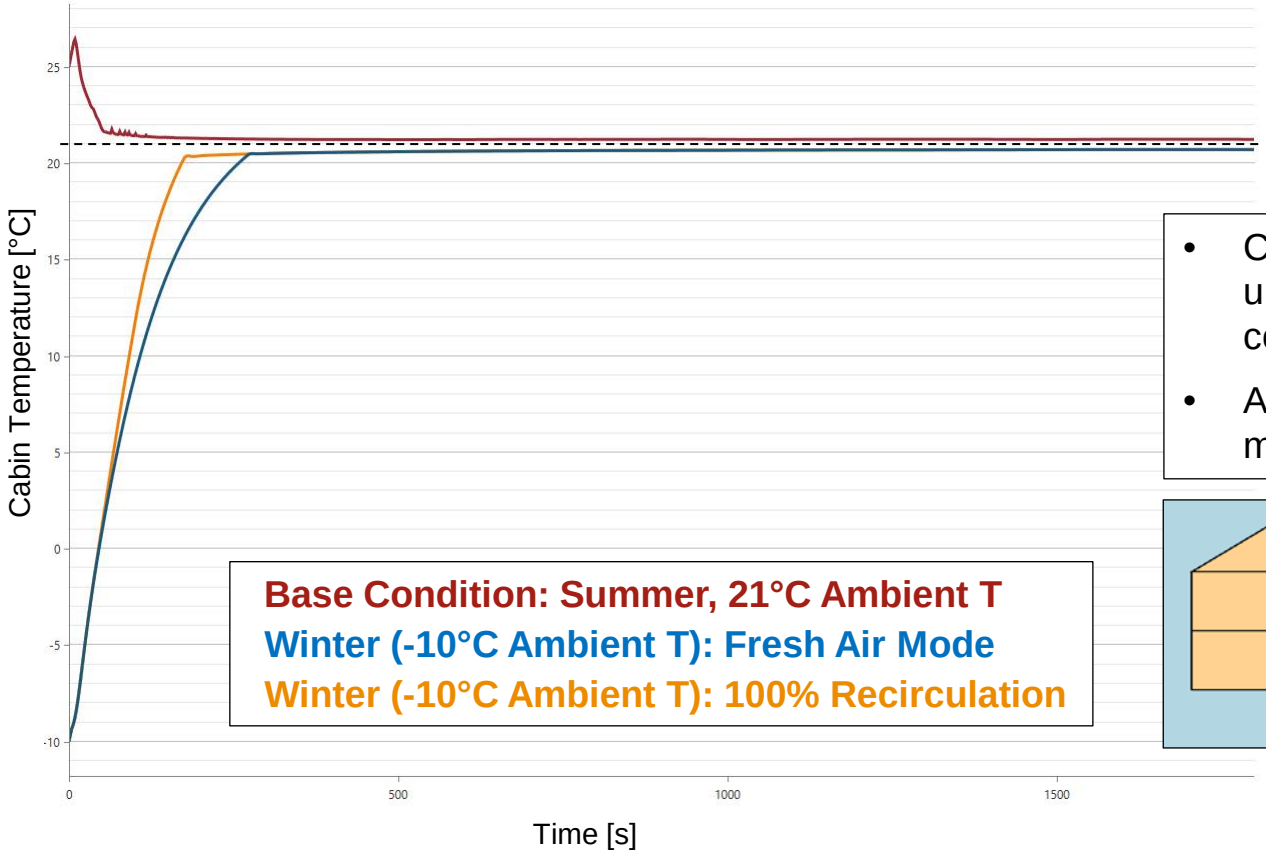
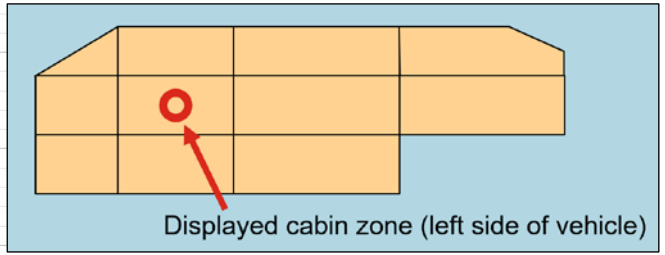
# Temperature Levels Cabin (Position driver torso, WLTC, 21°C cabin target T)




- Cabin air recirculation speeds up cabin warm-up in winter conditions (for same PTC heater)
- Available heater power is used more efficiently

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# Summary

- Experimental GXC Coating of passenger cabin windows efficiently prevents window fogging even at cold ambient conditions and in humid conditions inside the cabin.
- Condensation occurs inside the windows as a transparent and clear film
- This allows very high recirculation air rates in winter conditions

- **The result is a vehicle range improvement of more than 10% (for the WLTC) compared to the same vehicle in fresh air mode!**

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INSPIRING **INNOVATION.**