# Electric Vehicle Cabins Virtual Prototyping

## The right balance between thermal comfort and extended range


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20th of May 2019

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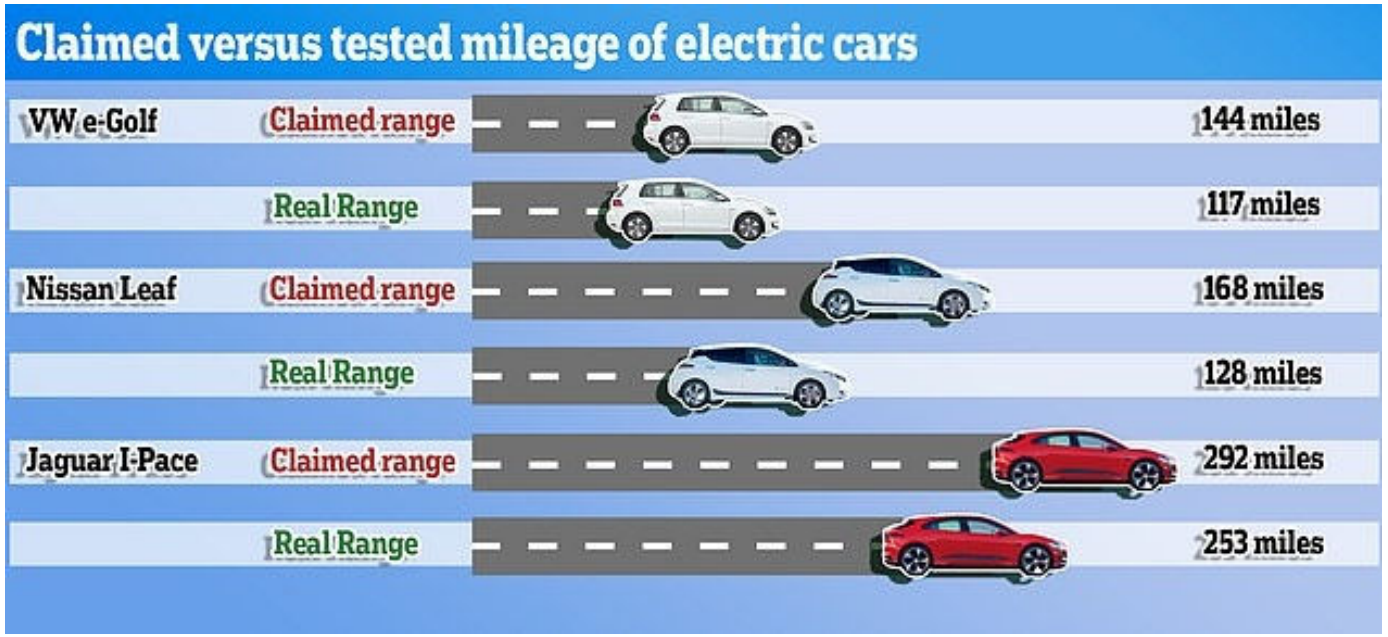
www.esi-group.com

# Current challenge with electric vehicles

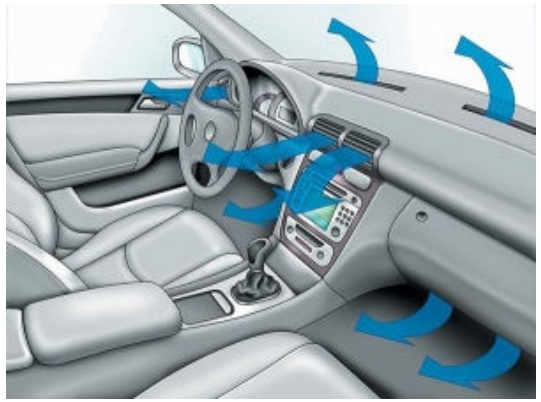
## The issue

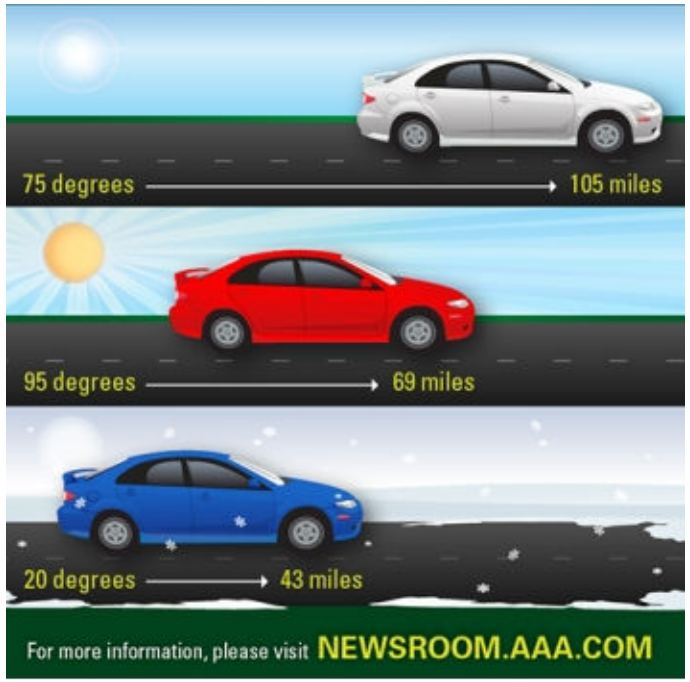


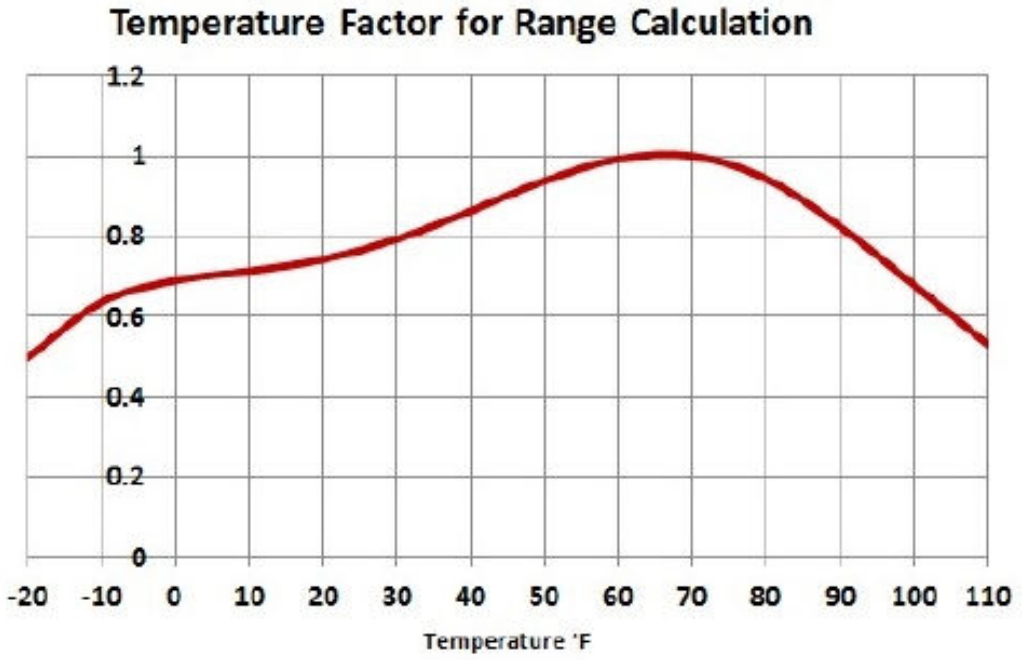

The range in real operating conditions is significantly lower than the claimed/nominal one.

# Current challenge with electric vehicles

## The root cause






The HVAC system has a significant energy consumption and impact on the range.

# Current challenge with electric vehicles

## The solution under implementation

| USA data | | |
|---|---|---|
| **1.59** | **1.90** | **2.35** |
| Average vehicle occupancy in US **cars** | Average vehicle occupancy in US **SUVs** | Average vehicle occupancy in US **VANs** |
| **Germany data** | | |
| **1.20** | **1.50** | **1.70** |
| Average vehicle occupancies in German commuting traffic | Average vehicle occupancies in Germany | Average vehicle occupancies in German leisure time traffic |

Reference: Gentherm presentation a IQPC Seating conference in Dec 2017

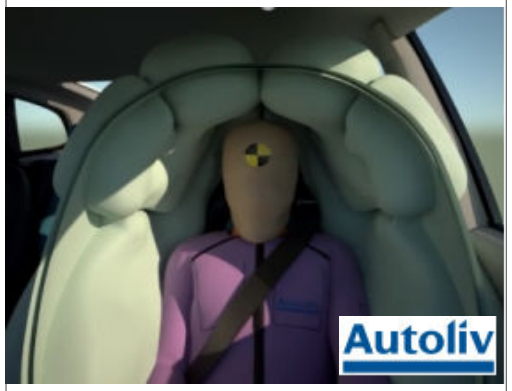
The solution is to rationalize HVAC energy consumption by adapting to car occupancy and relocate at least partially HVAC systems to the seats.

# How to innovate on seats ?

## Current status

Necessary use of new materials with no long experience and related best practices

**Light**

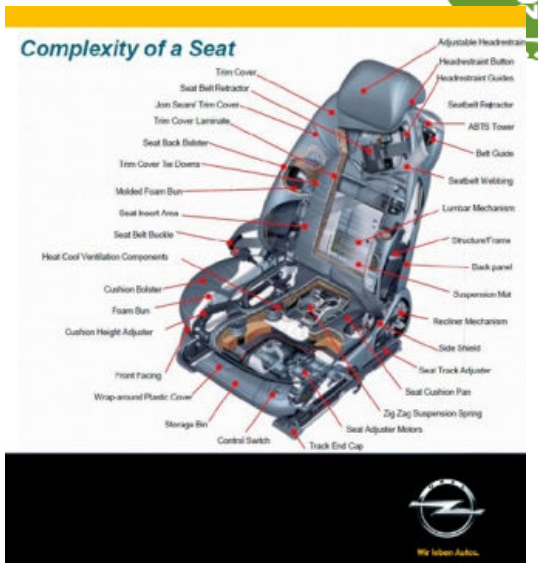



Heavy introduction of safety equipments to the seat, lone equipment following the passenger

**Autonomous**


Heavy introduction of HVAC equipments to the seat, lone equipment following the passenger

**Electric**




**CONSEQUENCE**

**COMPLEXITY**

# How to innovate on seats ?

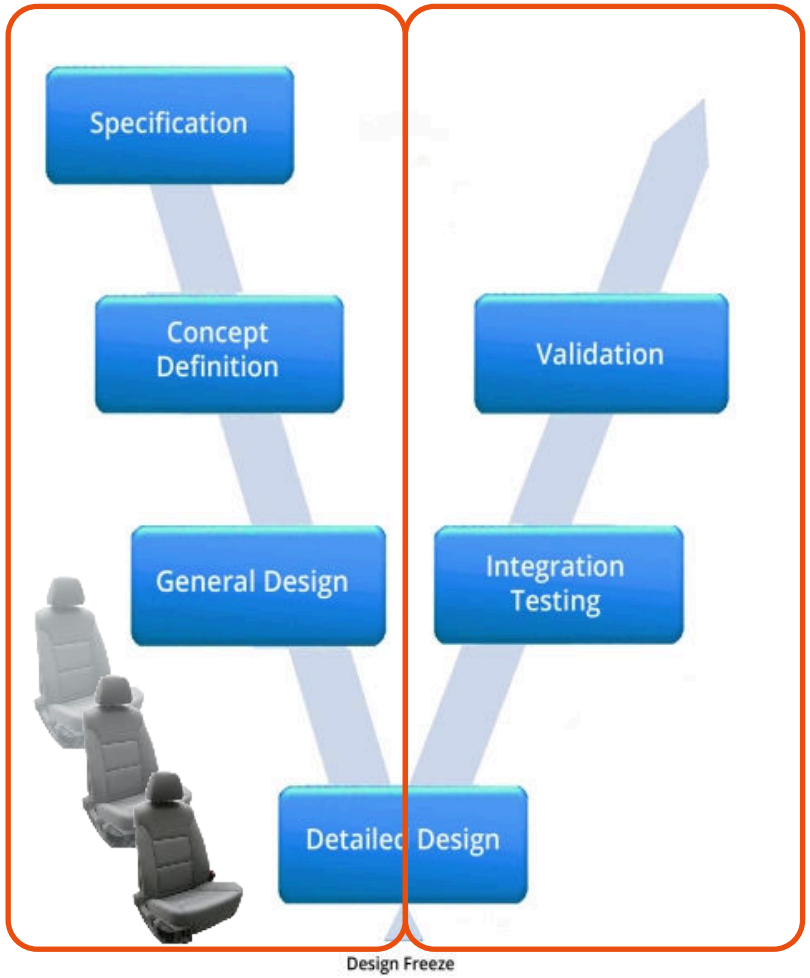
## Traditional seat development process

**BEFORE** design freeze


Scope limited to safety

Limited possibilities to iterate on real prototypes

Simulation calibrated with real prototypes




**AFTER design freeze**

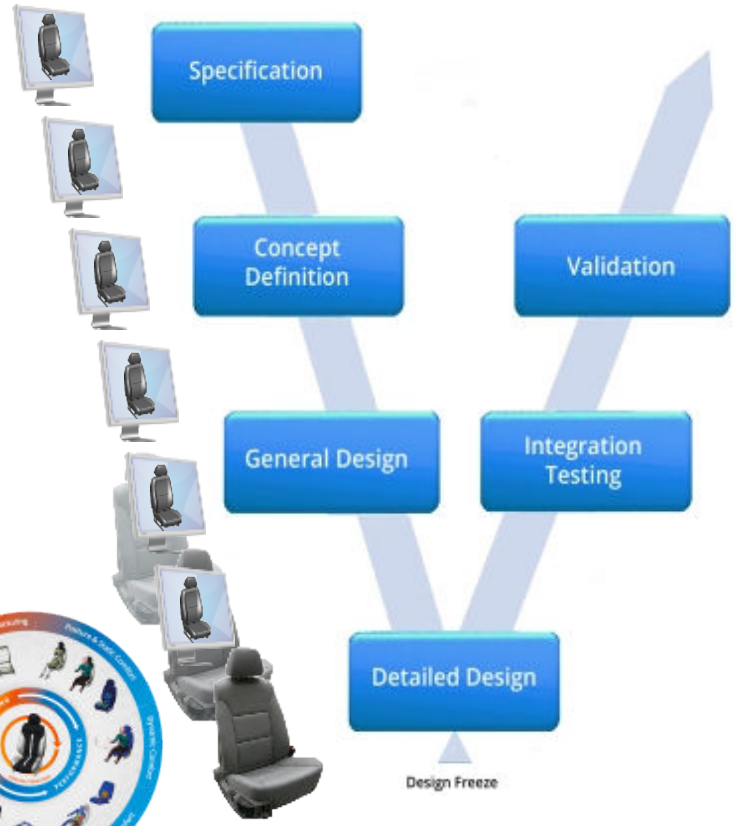
Potential discovery of other issues


Costly counter measures with related delays

Or lower quality

# How to innovate on seats ?

## Virtual prototyping




Handle iterations **virtually** to diminish the costs and enable many more variants

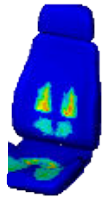

Move the iterations **upstream** in the development process to anticipate potential issues

Manage **simultaneously all performances** to make the right trade-offs

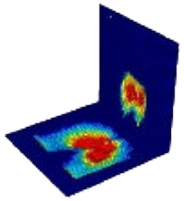
Innovate in confidence

# How to innovate on seats ?

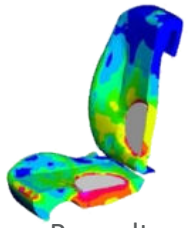
## Industrial testimonials examples

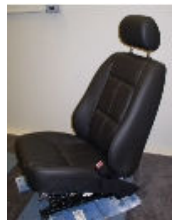

Hongik Uni.
DHM
2005


BMW
VDI
2005


Hyundai
DHM
2007


Ford
CTI
2007


Renault
IQPC
2007

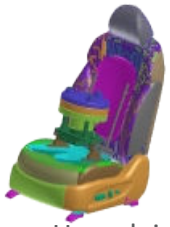

Ford
DHM
2007


Renault
SIA
2008


Ford
SAE
2011


Ford
NAFEMS
2011


GM
SAE
2012


Hyundai
IQPC
2013


Tachi-S
2015


Lear
DHM
2016


Grupo Antolin
EFF
2016


JSP
2017


Ford
SAE
2018

https://www

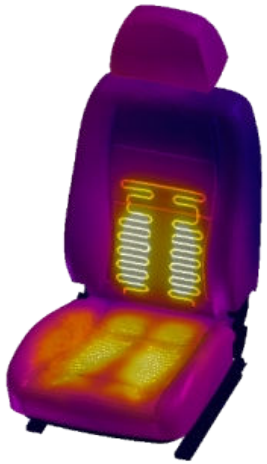
**www.esi-group.com/virtual-seat**

# Virtual Prototyping for thermal management

## Phenomena to be taken into account

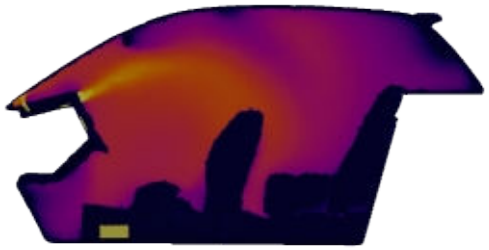
Active contributor through its thermoregulation + comfort assessor

**Human**



Passive and active systems, heating and cooling, conduction and ventilation, energy consumption

**Seat**



Heating and cooling, Ventilation (+ Radiation), energy consumption

**Cabin**

**COUPLED DOMAINS WITH HEAT EXCHANGES BETWEEN**

# Virtual Prototyping for thermal management

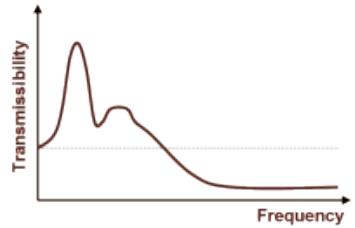
## Human Models

**Human database**

**Sitting simulation**

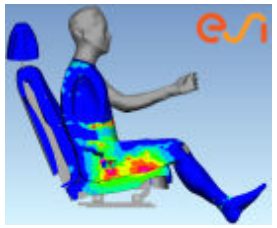
**Vibrations simulation**

**Vibrations Perf.**




Modal analysis, Transfer function, SEAT comfort index

**Static Comfort Perf.**



Pressure distribution, Posture

**Thermal simulation**

**Thermal Perf.**

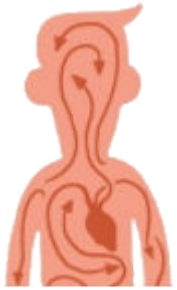
Temperature, Comfort score

**SAME HUMAN MODELS USED FOR ALL TESTS**

# Virtual Prototyping for thermal management

## Human Models

### Passive system modelling:



**Interior heat exchanges :**

- Conduction, Blood circulation, Basal metabolism, Muscle activity

**Exterior heat exchanges :**

- Convection, Conduction, Radiation, Respiration

### Active system Modeling :

**Heating mechanisms**

- Shivering
- Vasoconstriction

**Cooling mechanisms**

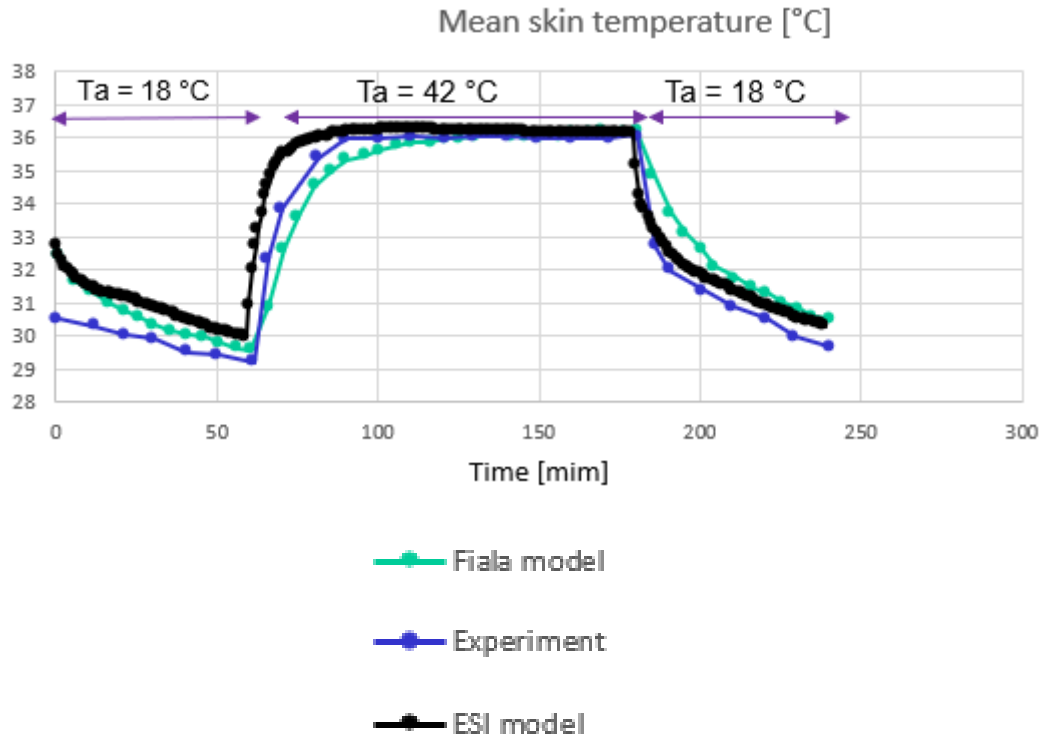
- Sweating
- Vasodilatation

- Body decomposition to take into account the high asymmetry of the thermal envt
- Anthropometries factors (age, gender, fat percentage, weight, height ...)
- Cloth database

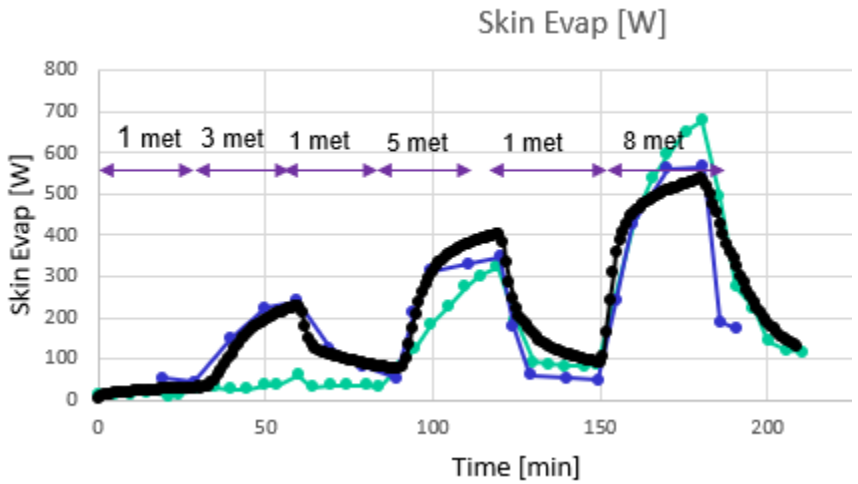
# Virtual Prototyping for thermal management

## Human Models : validation examples

### Changing ambient temperature …



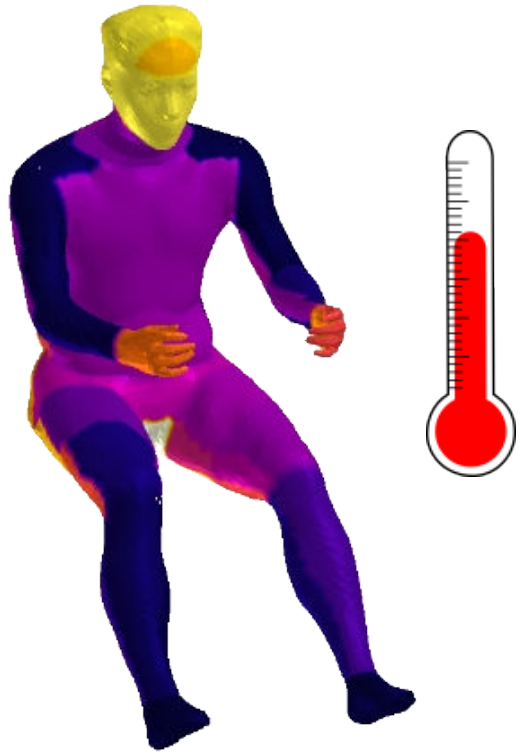

### Changing human activity …



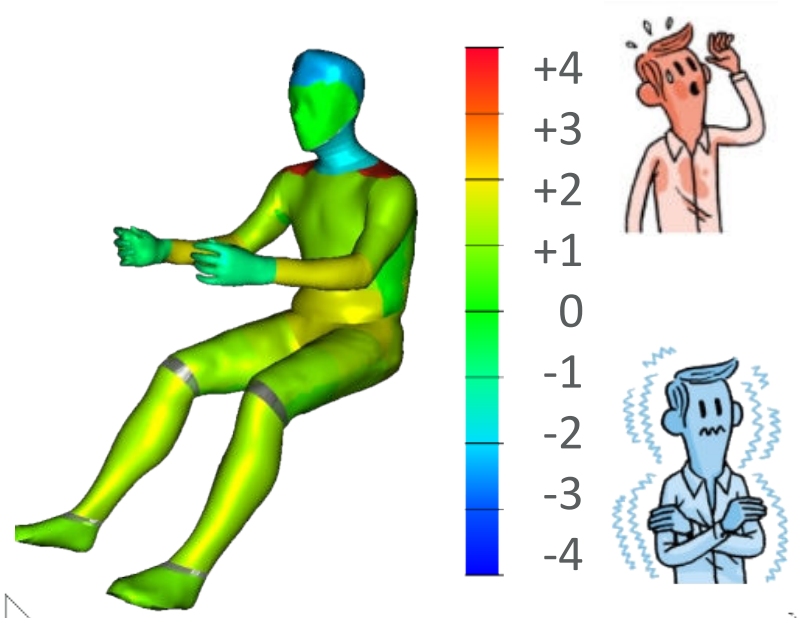

| Activity | Value in [met] |
|---|---|
| Sleeping | 0.9 met |
| Watching TV / screen | 1.0 met |
| Bicycling, very light effort | 3.0 met |
| Running | 8.0 met |

# Virtual Prototyping for thermal management

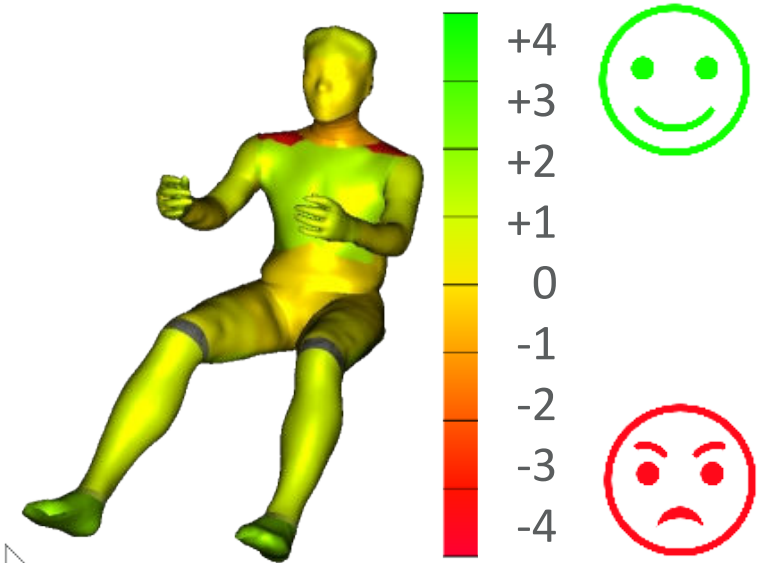
## Human Models



Temperature map




Sensation index (local and global)

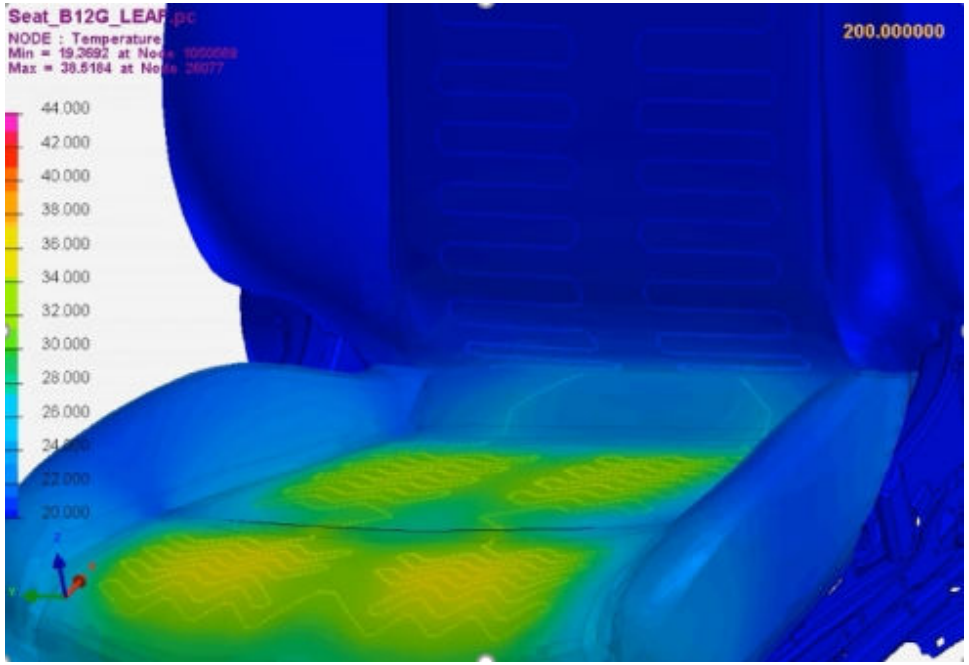



Comfort index (local and global)

# Virtual Prototyping for thermal management

## Seat Modelling

### Seats with heating pads




Seat Modelling for Nissan Leaf including heating pads and thermostats

### Seats with ventilation system

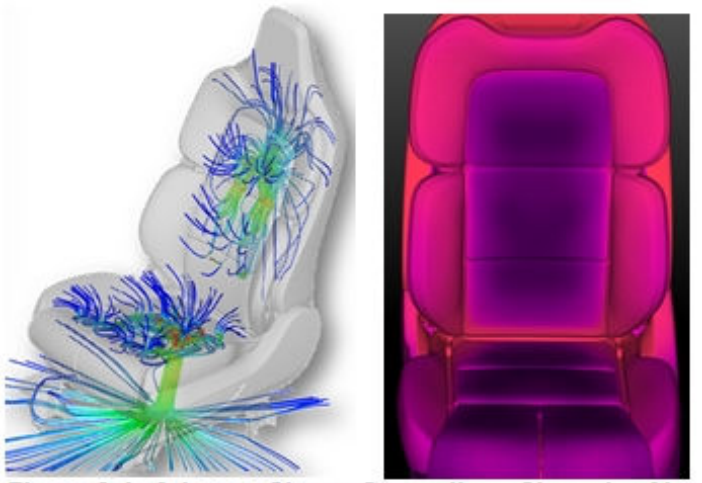


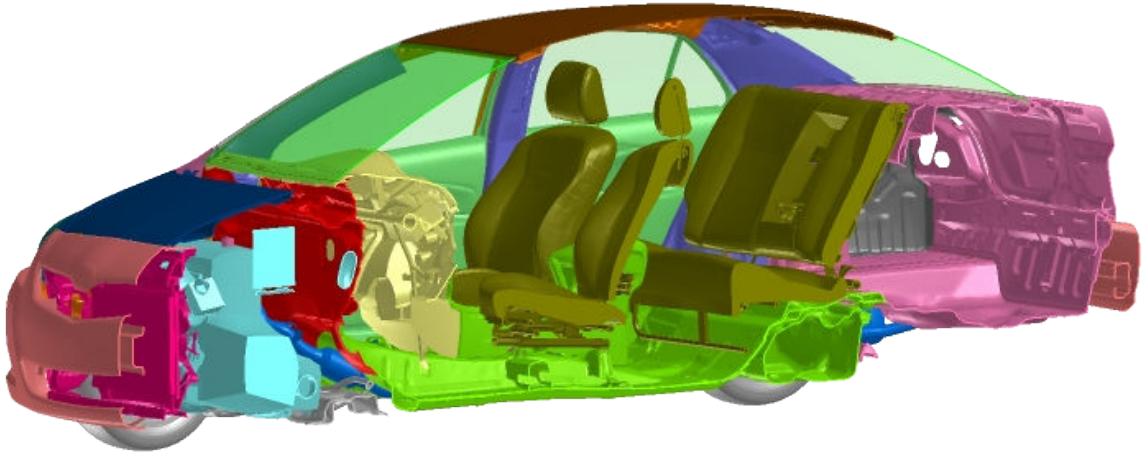
Figure 9 Left Image Shows Streamlines Show the Air Flow Path into the Seat and Ejected Under and Behind the Seat, Right Image Shows the Predicted Temperature Distribution

Figure 12 Surface Temperatures on the Occupied Seat

Seat Modelling for Ford including ventilation systems

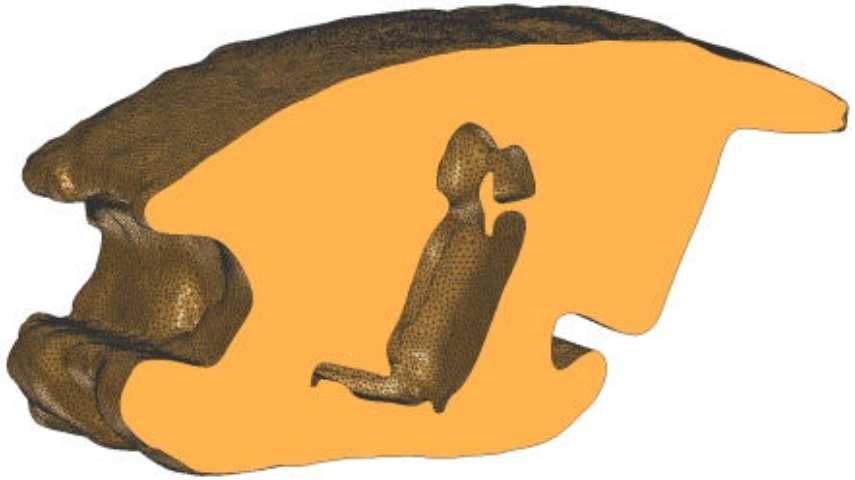
# Virtual Prototyping for thermal management

## Cabin Modelling

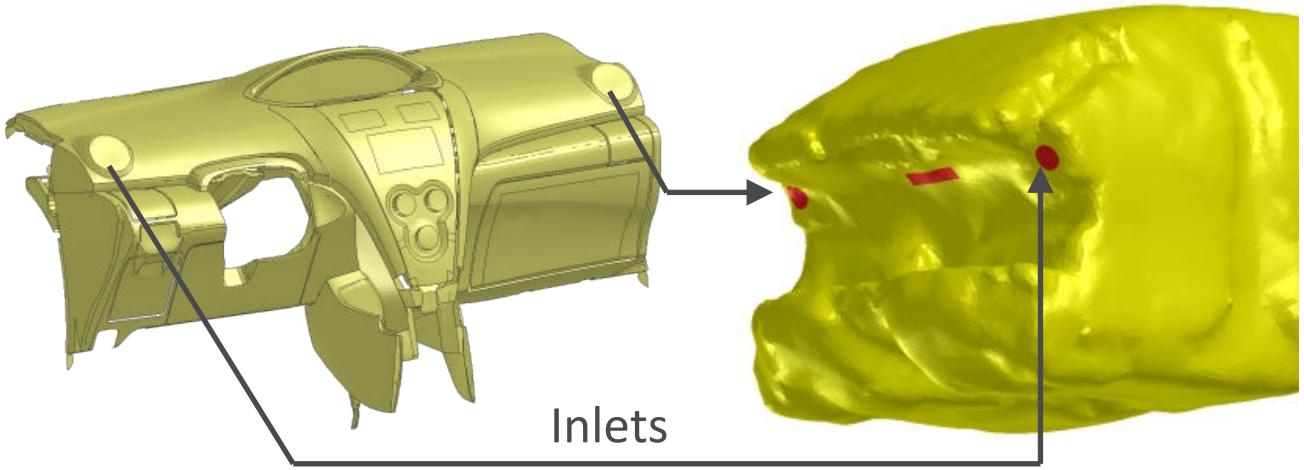


Cabin mesh

Occupied seat



Air mesh



# Virtual Prototyping for thermal management

## Application example

### Step 1 :

- Walking outside at a moderate speed to reach the car
- 2 min in an environment at -10°C and 80% humidity

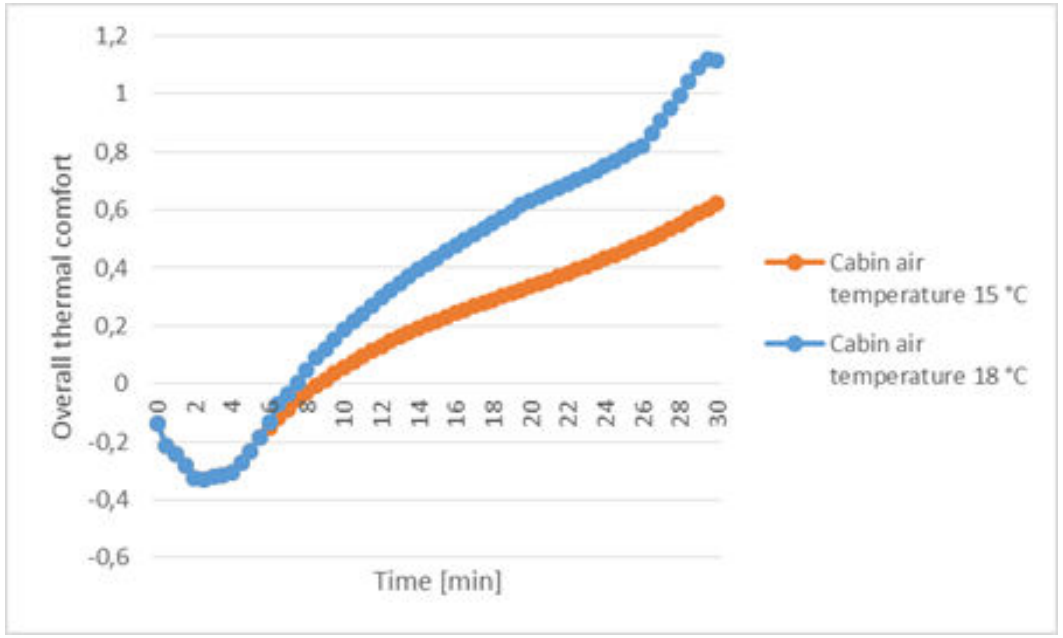
### Step 2 :

- Putting the HVAC on with 2 scenarios :
  - Once reaching an average temperature of 18°C
  - Once reaching an average temperature of 15°C

# Virtual Prototyping for thermal management

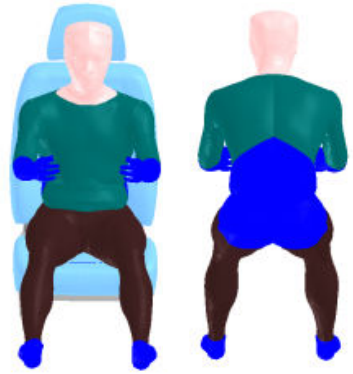
## Application example

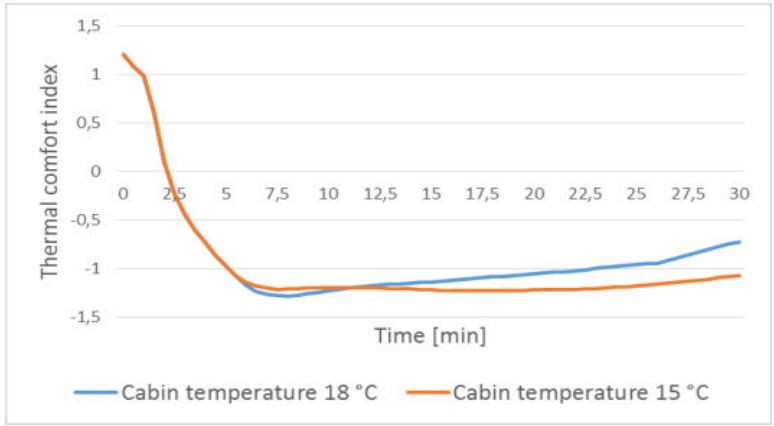
### Globally, as expected, comfort decreases




*Overall thermal comfort*

### But <u>locally</u>, only 4 areas significantly impacted






Replace global warming by local / less consuming heating equipments

# Virtual Prototyping for thermal management

## Application example

### Step 1 :

- Walking outside at a moderate speed to reach the car
- 2 min in an environment at -10°C and 80% humidity

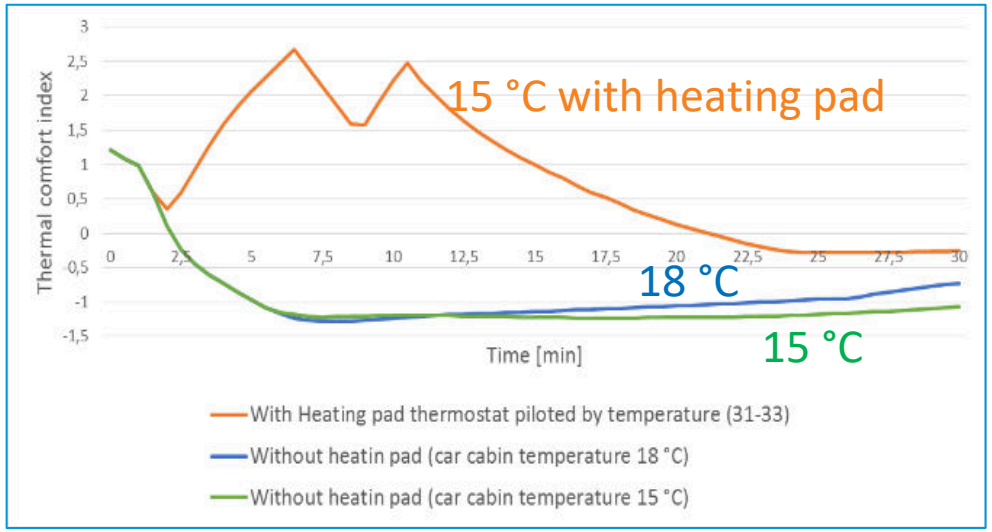
### Step 2 :

- Putting the HVAC on with **3** scenarios :
  - Once reaching an average temperature of 18°C
  - Once reaching an average temperature of 15°C
  - Once reaching an average temperature of 15°C and a seat heating pad

# Virtual Prototyping for thermal management

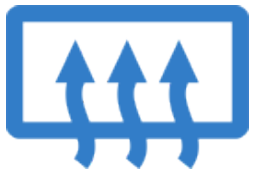
## Application example

### Improved Comfort



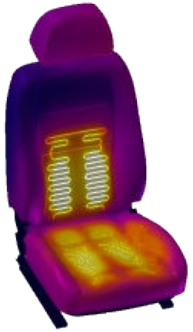

*Lower abdomen thermal comfort*

### Reduced Energy Consumption



**Power consumption**. In a modern **automobile**, the A/C system will use around 4 horsepower (3 kW) of the engine's **power**, thus increasing fuel **consumption** of the **vehicle**.

Automobile air conditioning - Wikipedia
https://en.wikipedia.org/wiki/Automobile_air_conditioning



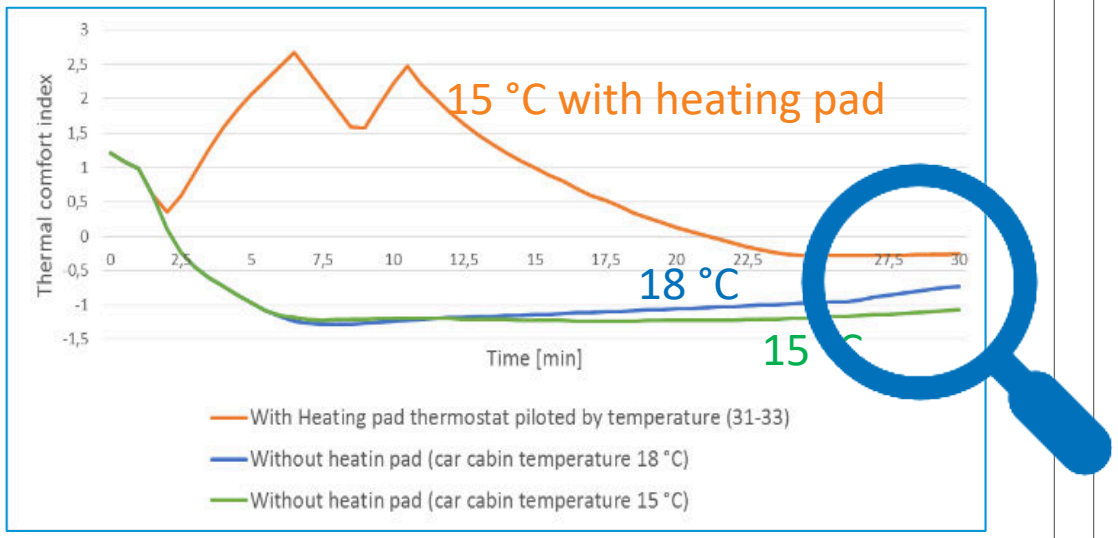
Average **Energy Usage**. A typical electric mattress **pad consumes** approximately 60 to 90 watts on the high settings. This **usage** is per side, however, so an entire **pad** can **consume** 120 to 180 watts on average. Translated into money, this means the average **pad** is consuming about 2 to 3 cents if run for an entire night.

How Much Electricity Does a Heated Mattress Pad Use? | Hunker
https://www.hunker.com/13403955/how-much-electricity-does-a-heated-mattress-pad-use

# Virtual Prototyping for thermal management

## Application example

### Improved Comfort but still negative




*Lower abdomen thermal comfort*

Replace temperature-based thermostat by activation/deactivation based on human sensation

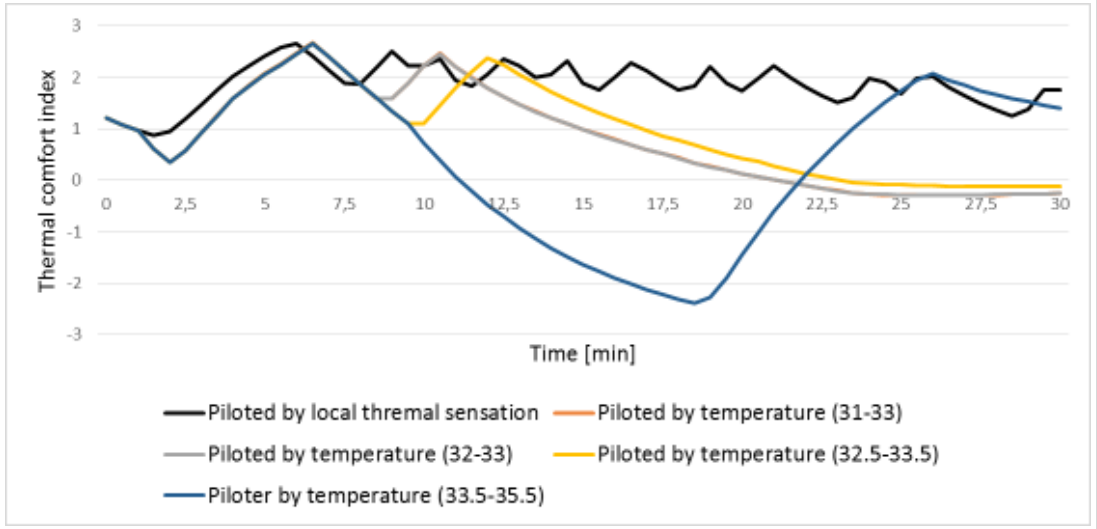
"I start feeling too hot."
→ Heating pad is deactivated.

"I start feeling too cold."
→ Heating pad is activated.

# Virtual Prototyping for thermal management

## Application example

### Improved Comfort




*Thermal comfort is optimal when keeping the sensation neutral (neither too hot, neither too cold).*

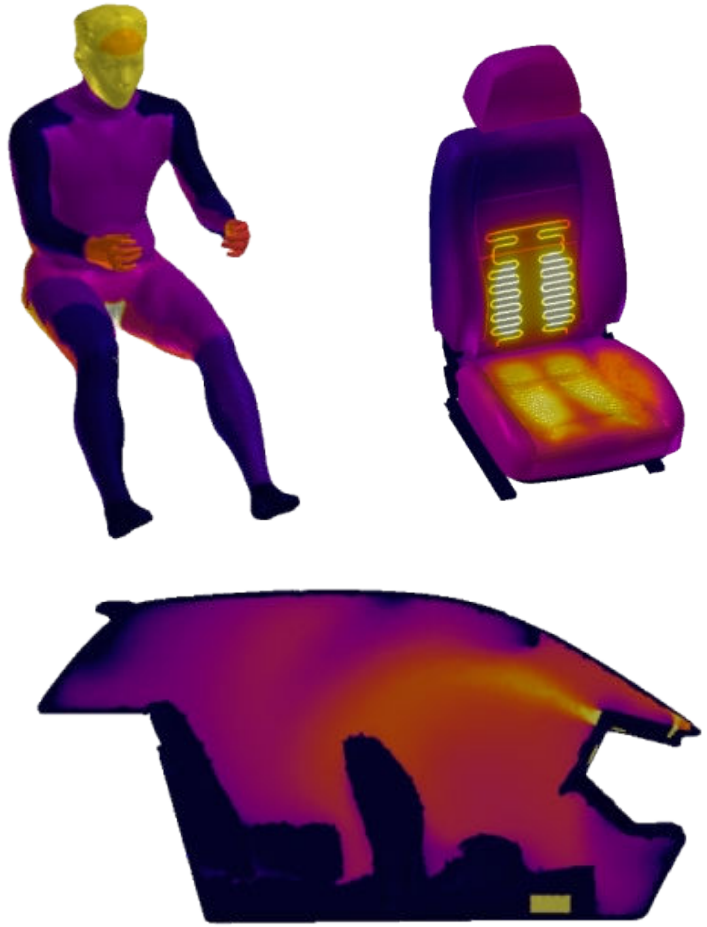
Replace temperature-based thermostat by activation/deactivation based on human sensation

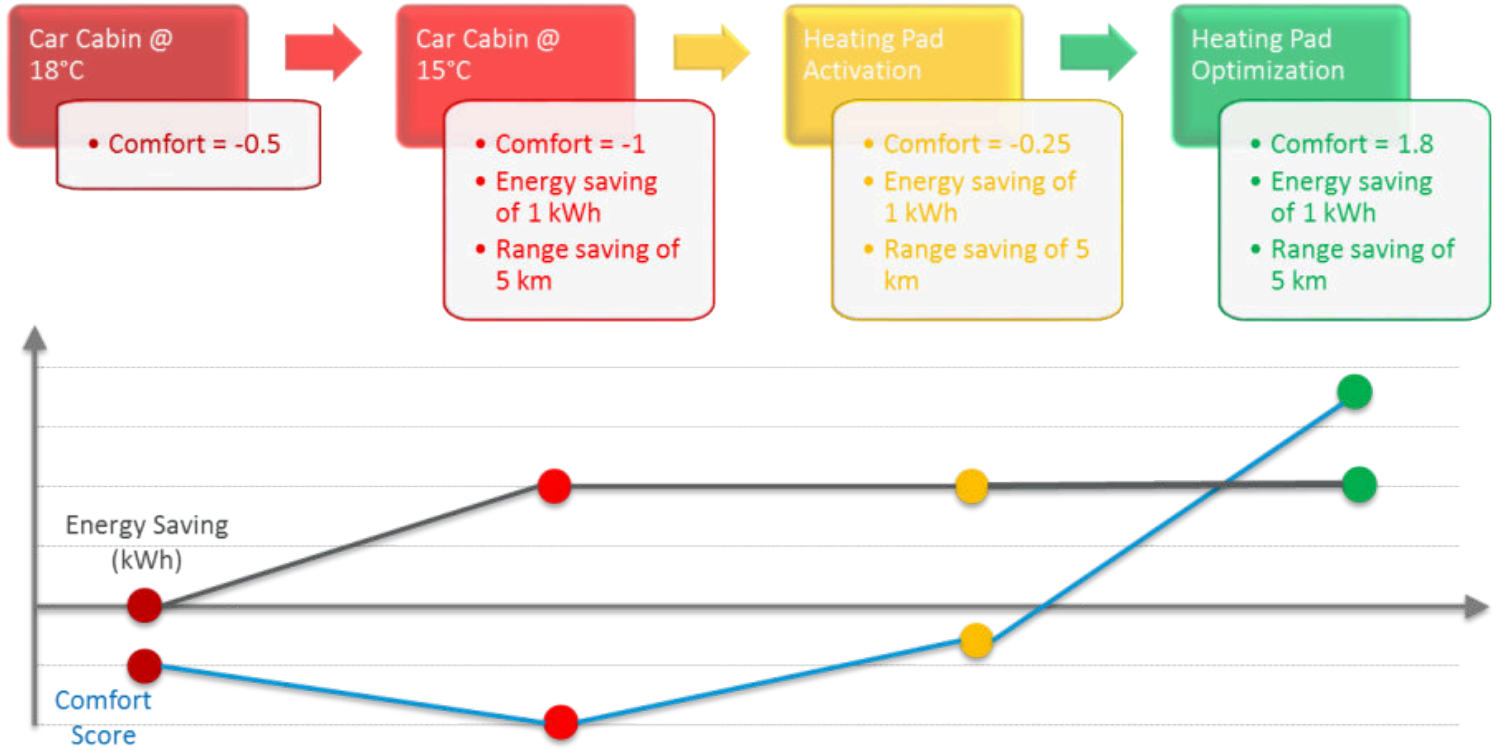
"I start feeling too hot."
→ Heating pad is deactivated.

"I start feeling too cold."
→ Heating pad is activated.

# Virtual Prototyping for thermal management

## Conclusion





# THANK YOU