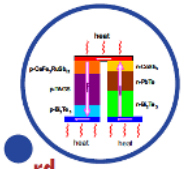
RENAULT TRUCKS

Joint Company
Volvo Group

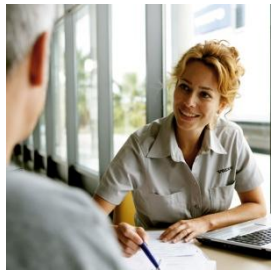
RENOTER Project



3rd Thermoelectric Applications Workshop: 20-22 March 2012 in Baltimore (MI)

Introduction - Volvo Group

Volvo Trucks	Renault Trucks	Mack Trucks	UD Trucks
			

Buses	Construction Equipment	Volvo Penta	Volvo Aero	Financial Services
				

1) Introduction

RENOTER acronym for:

"**R**écupération d'**EN**ergie à l'échappement d'un m**O**teur par **Th**ER**R**moélectricité"

- 8 partners (and 3 laboratories)
- Q4-2008 to Q2-2012
- 4M€ project
- Partially funded by French Government

1) Project Goals

- Diesel : **100We** NEDC and **300We** customer cycle
- Gasoline : **500We** on customer duty cycle

- **1kWe** on cruise point (50% load)

- Focus on **cheap, efficient**, and **sustainable** TE materials
- Work on **material integration** and scaling-up **process**
- Target cost is 0.3 – 1.3 $/$W_e$ (all included)

2) Targeted applications

- 2.0L diesel passenger car (150hp)
- FE = 45 mpg
- Exhaust line chosen as heat source (330°C – 25g/s)*

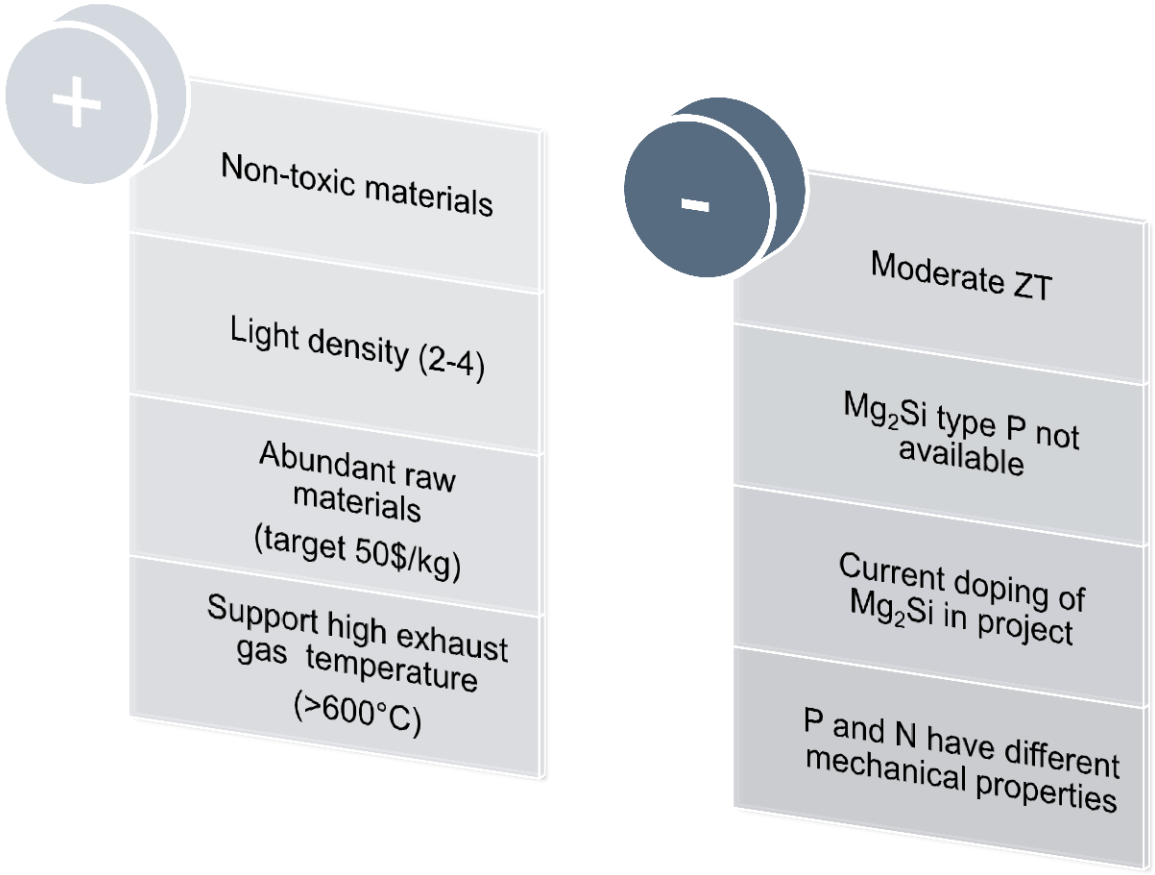
- Heavy duty truck with 11L displacement engine (460hp)
- FE = 6.8 mpg
- EGR Cooler selected as heat source (400°C – 70g/s)

**EGR flow ~0 at full load*

3) Material development

Choice of **Silicide's** (made by hot pressing)

- N-type : Mg_2Si
- P-type : $MnSi_{1.77}$

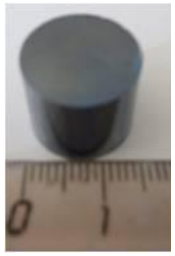


3) Materials development

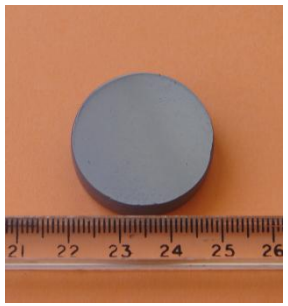
Iterative process of scaling-up in order to maintain ZT value

(MEB analysis and properties measurement)

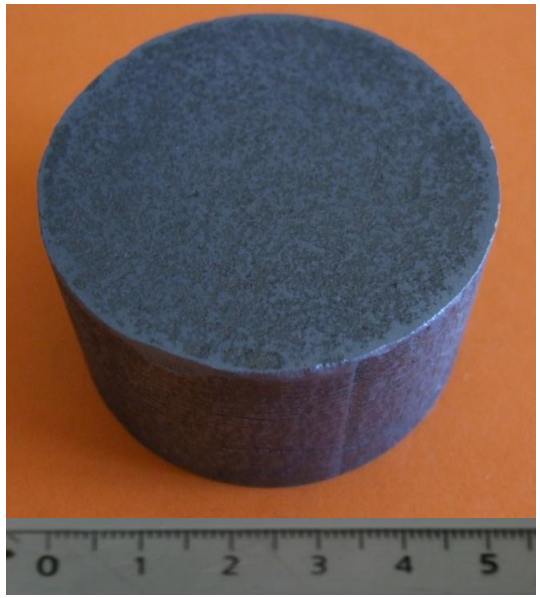
Ø8mm



Ø15mm

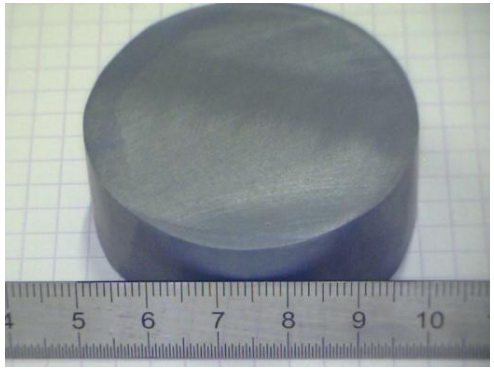


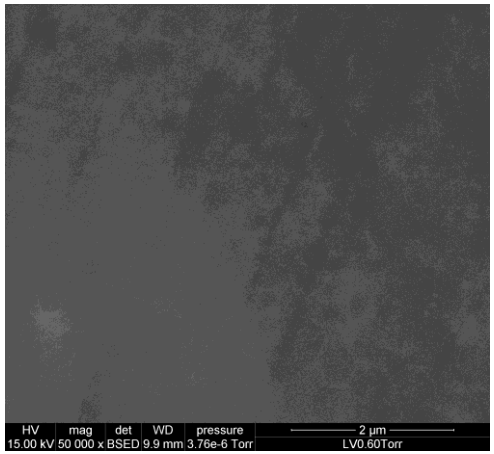
Ø30mm



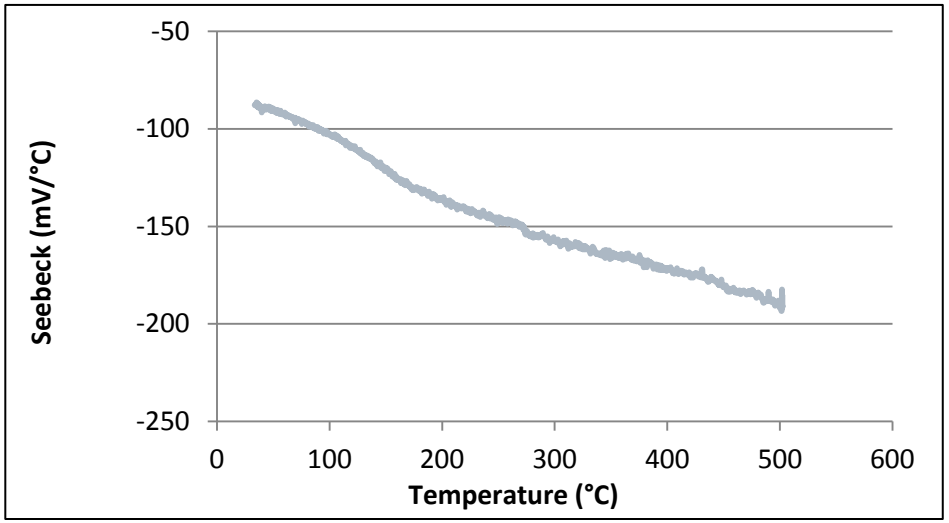
Ø50mm

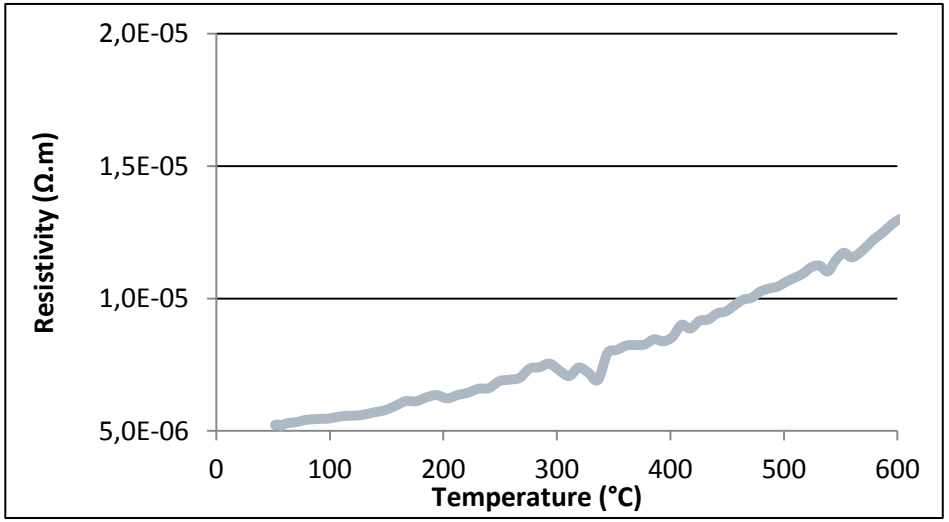
3) Materials development





Homogeneous samples

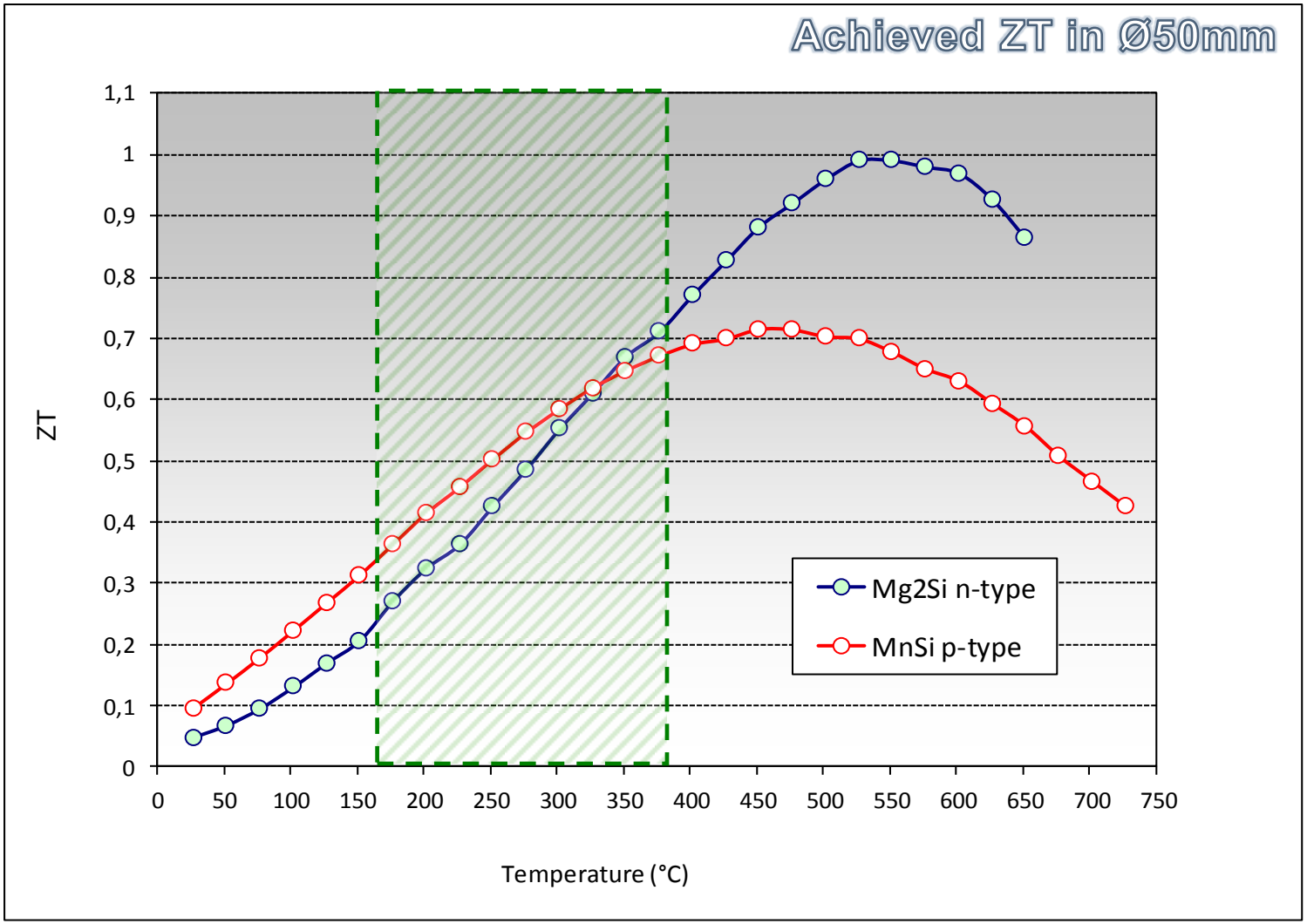




3) Materials development

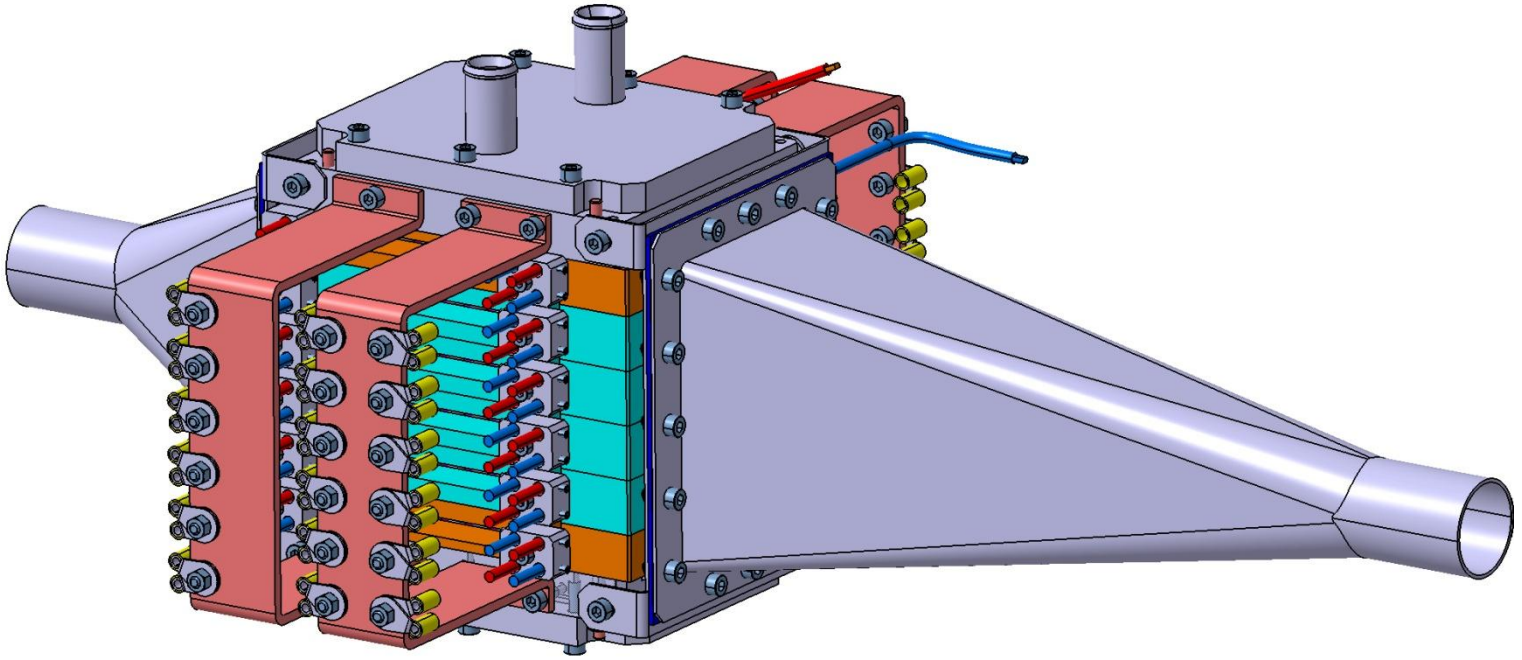
Successful lab. production of the legs for the project prototype (>1500)

3) Materials development

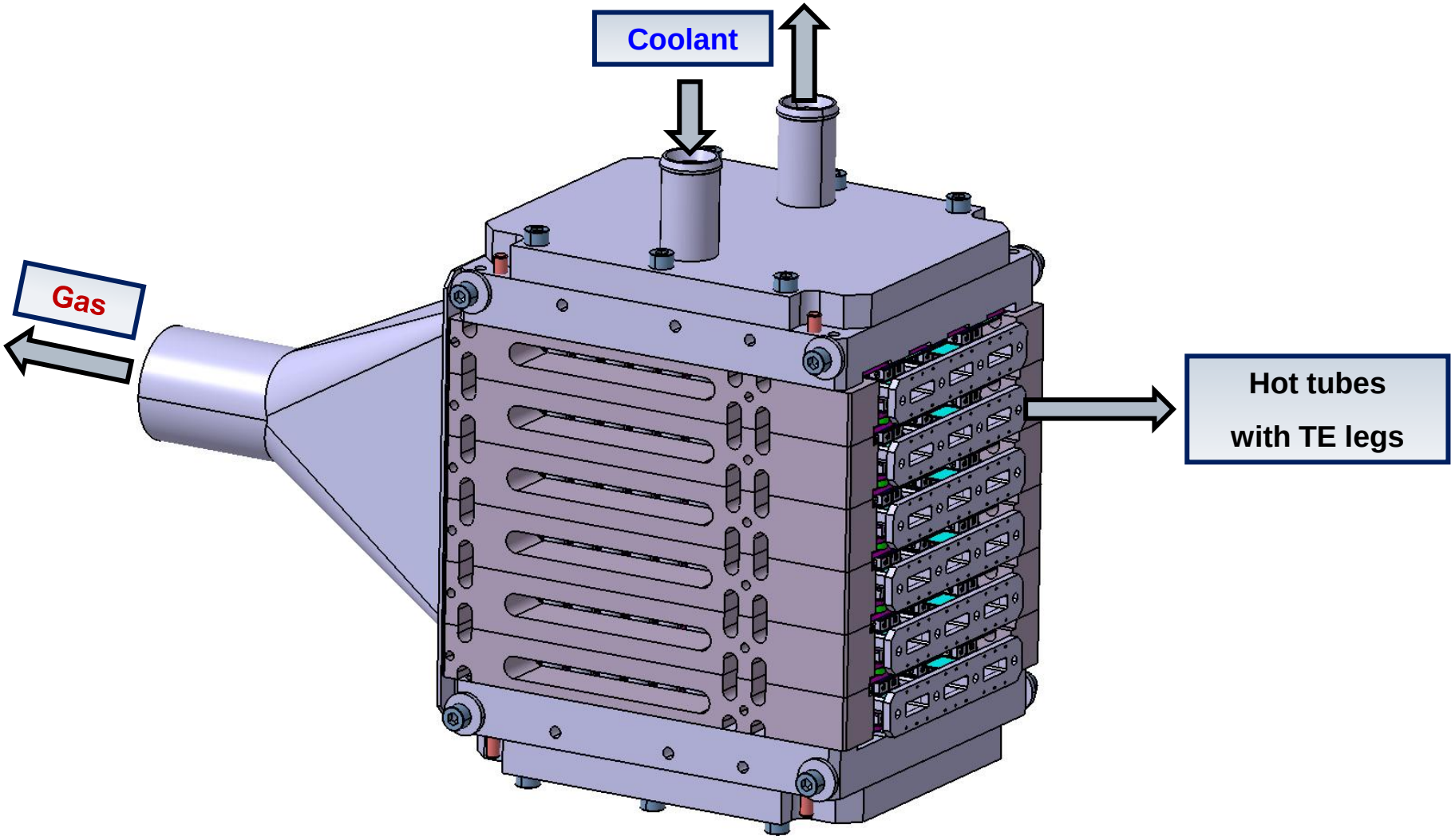


4) Integration in heat exchanger

- Novel heat exchanger design already presented (2010 Workshop)
- Multi-layer hot tube integrating e-circuit (i.e. TE legs directly on the hot tube) to combine functions

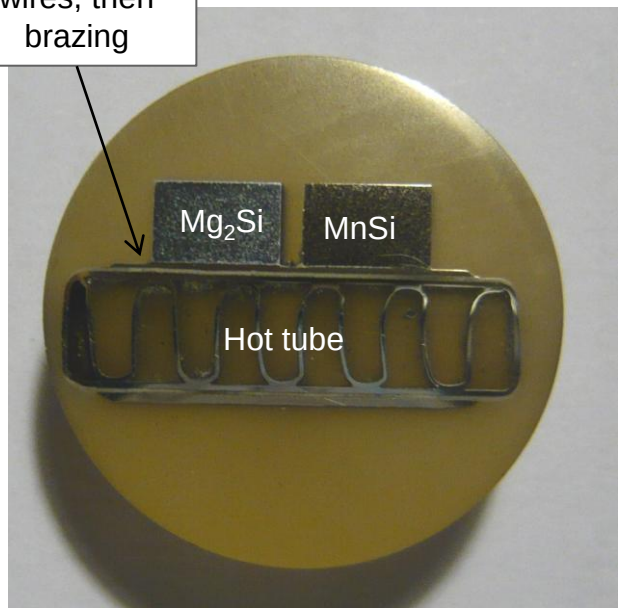


4) Integration in heat exchanger



4) Integration in heat exchanger

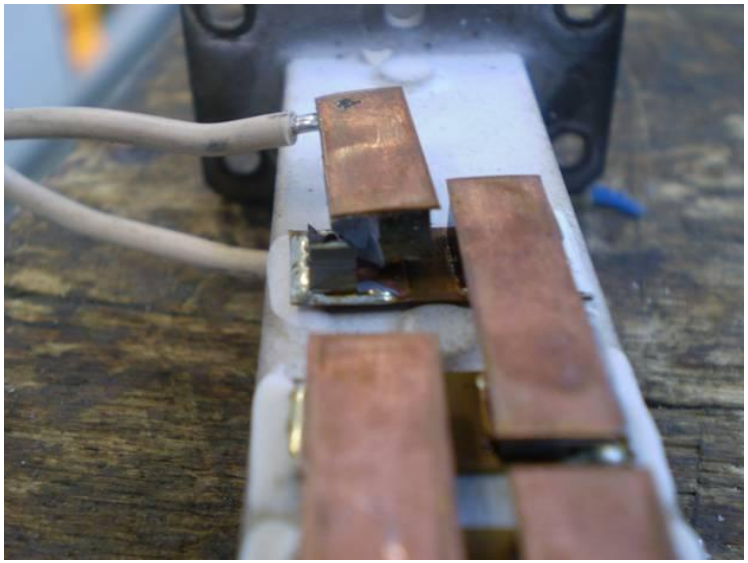
Spraying of ceramic and of electrical wires, then brazing

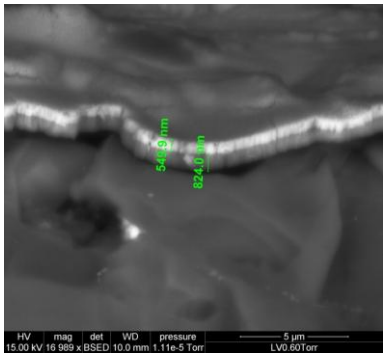


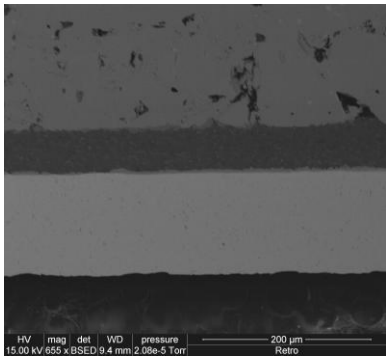
- Maximise ΔT over the legs
- Minimize electrical resistance of the circuit (leg / contact / electrical patterns)
- Best electrical insulation on hot tube
- Secure mechanical strength

4) Integration in heat exchanger

- “One shot” brazing of P&N legs onto hot tubes
- Extended multi skill step-by-step team work to address successfully all technical issues
- Achievements ⇨ No legs failures, and $R_{brazing}$ < 20% of R_{legs}



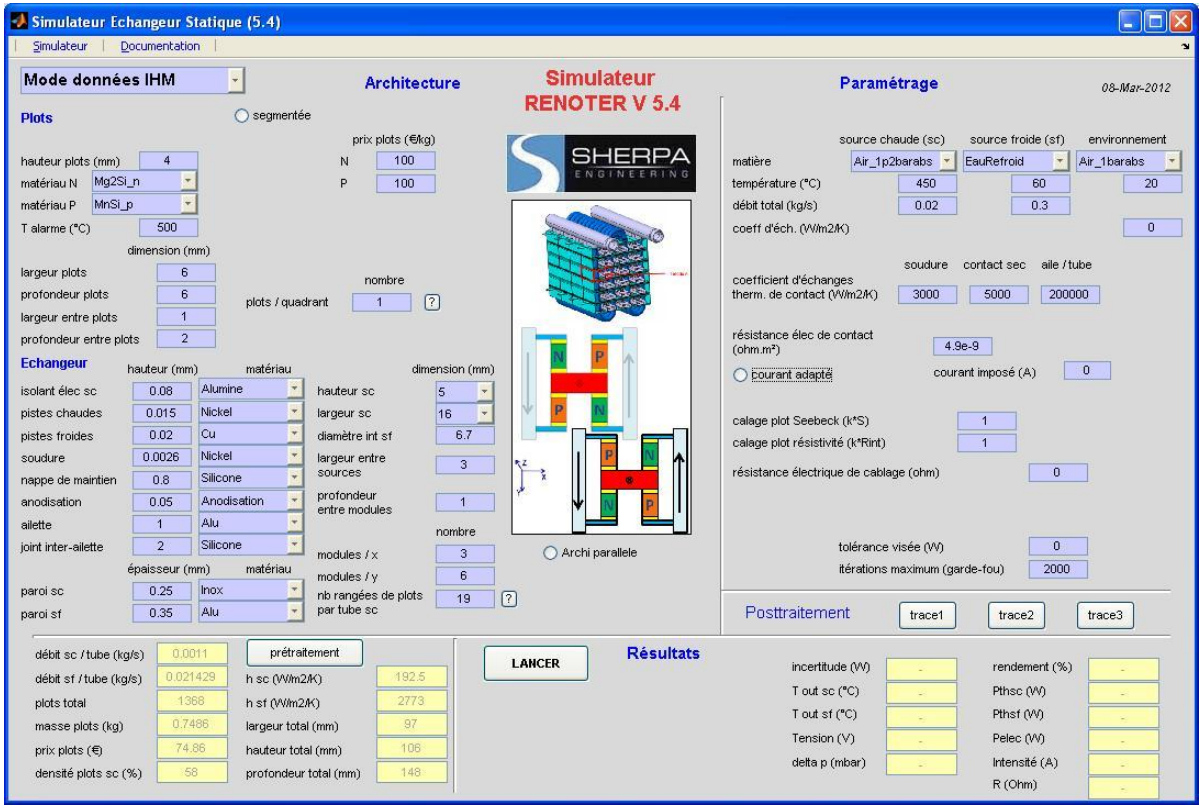


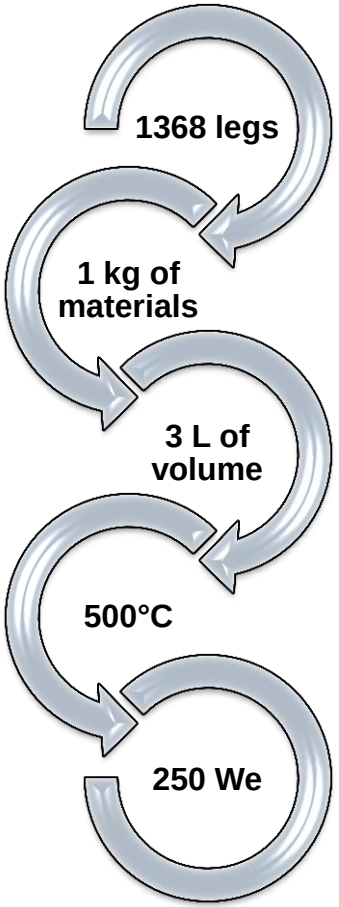


Typical R_{leg}=1.3-1.7mΩ

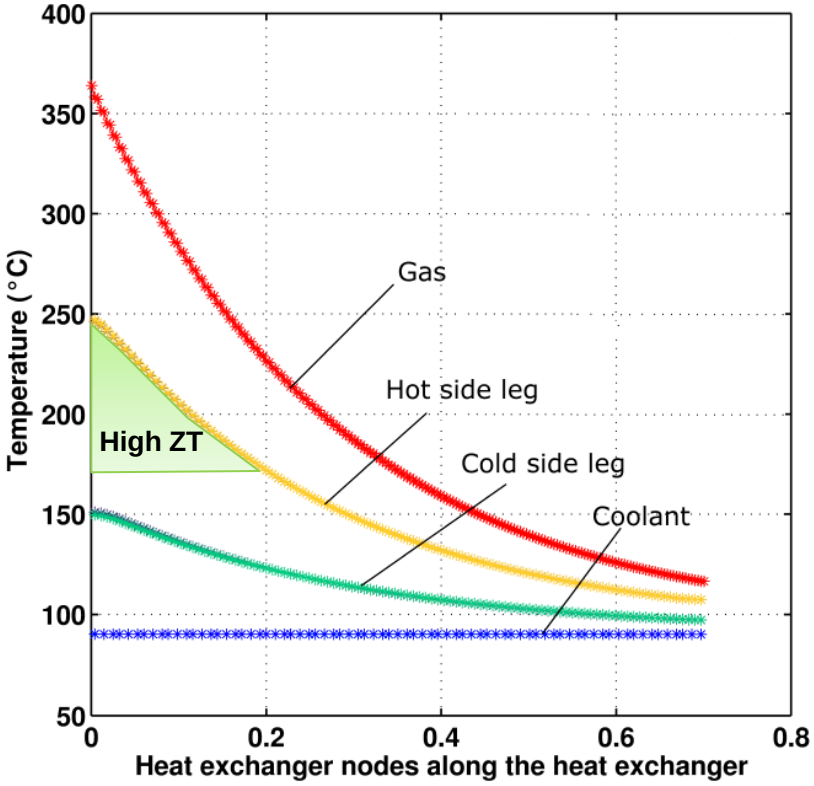
5) Simulation and testing

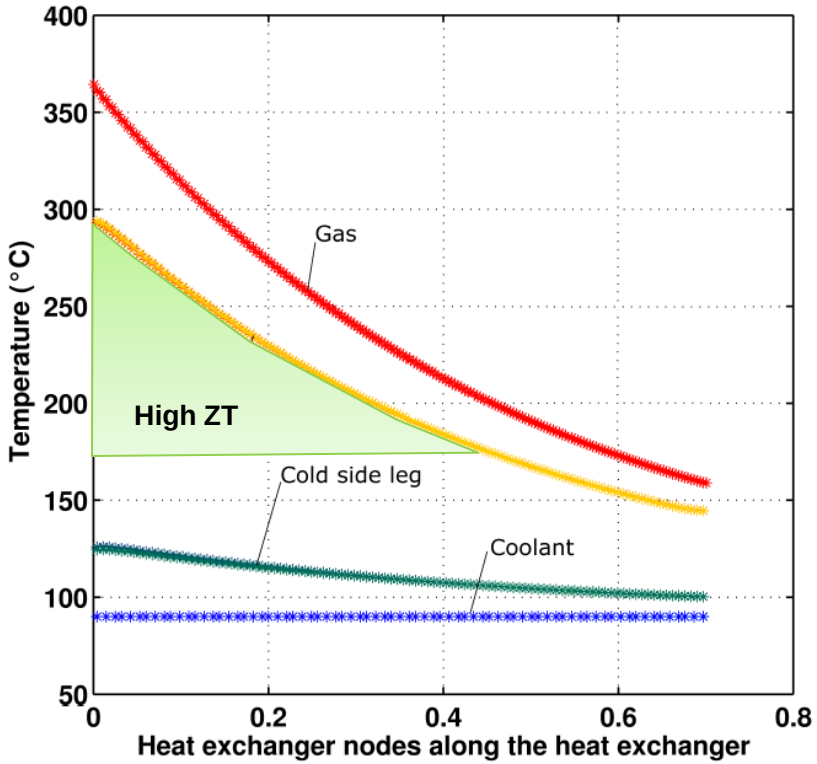
Mock-up sizing for feasibility test based on car application





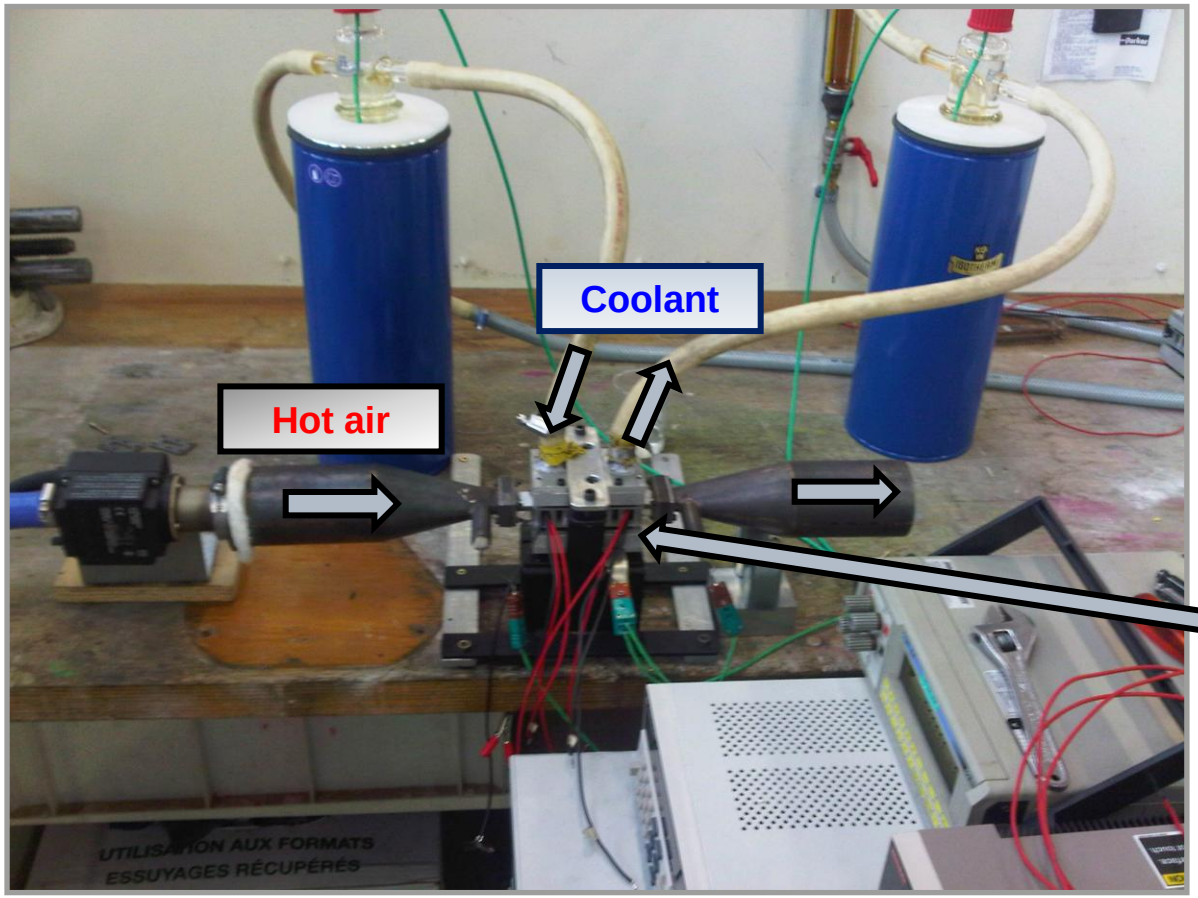
5) Simulation and testing



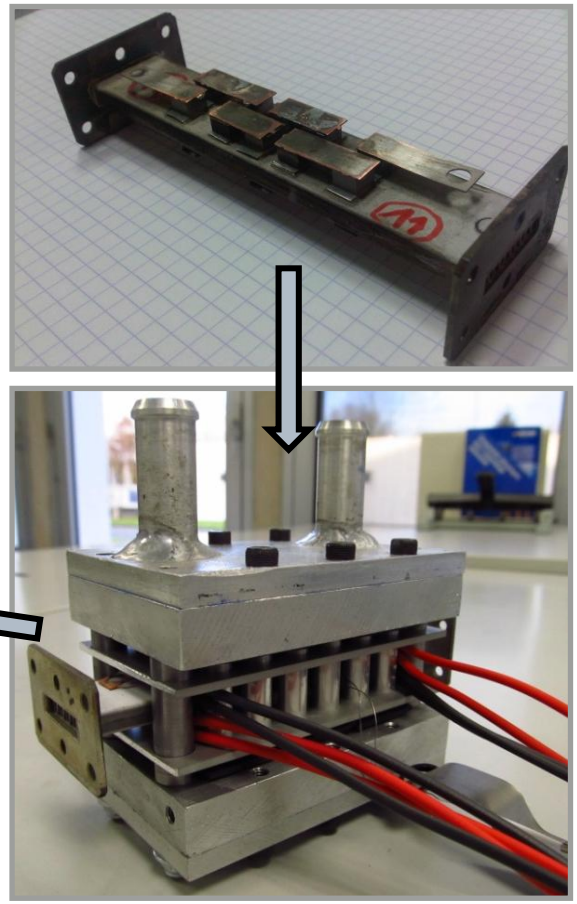


Effect of plots high (4mm vs. 12mm) on temperatures distribution

5) Simulation and testing



1 small tube (10 legs)



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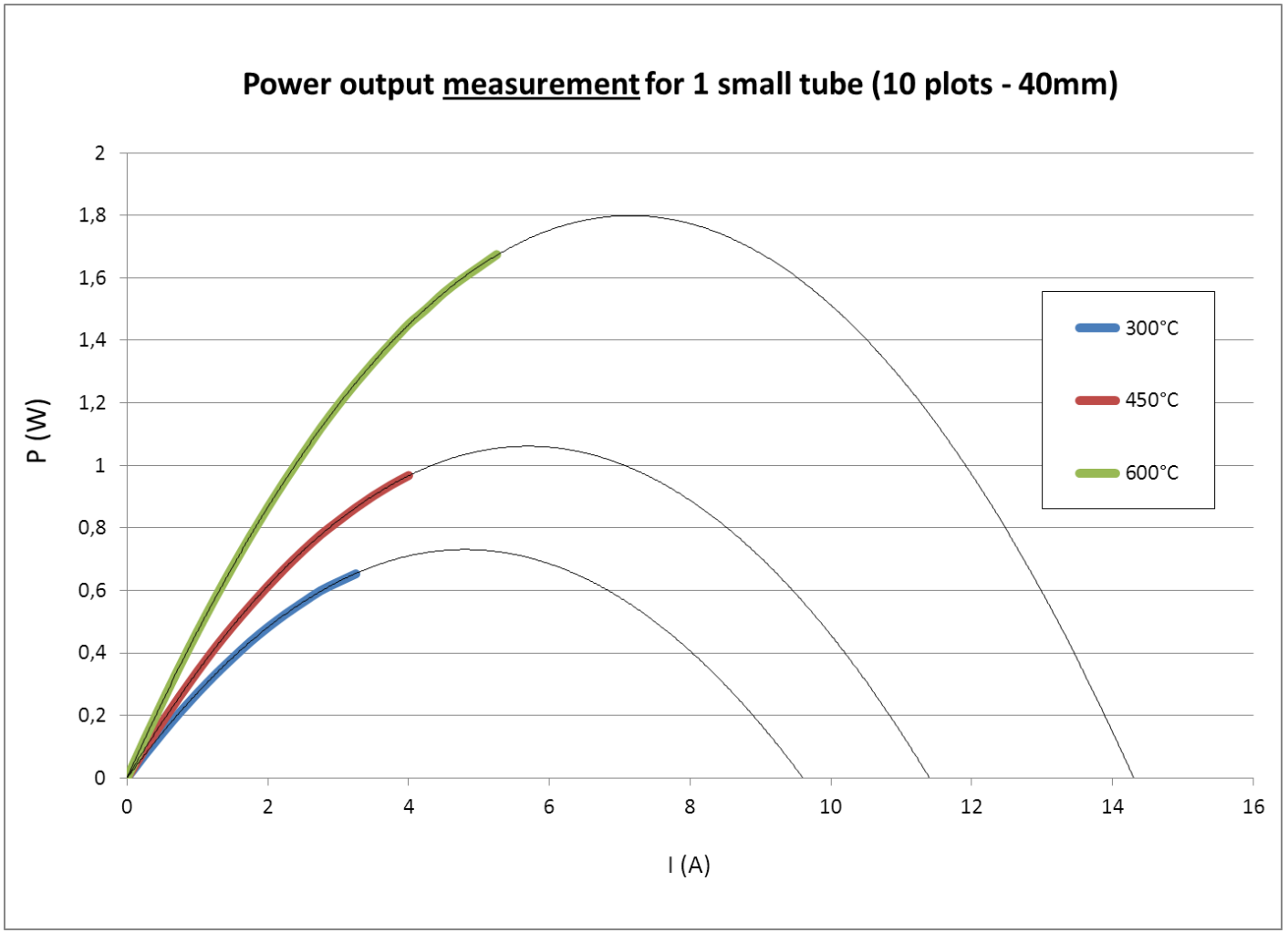
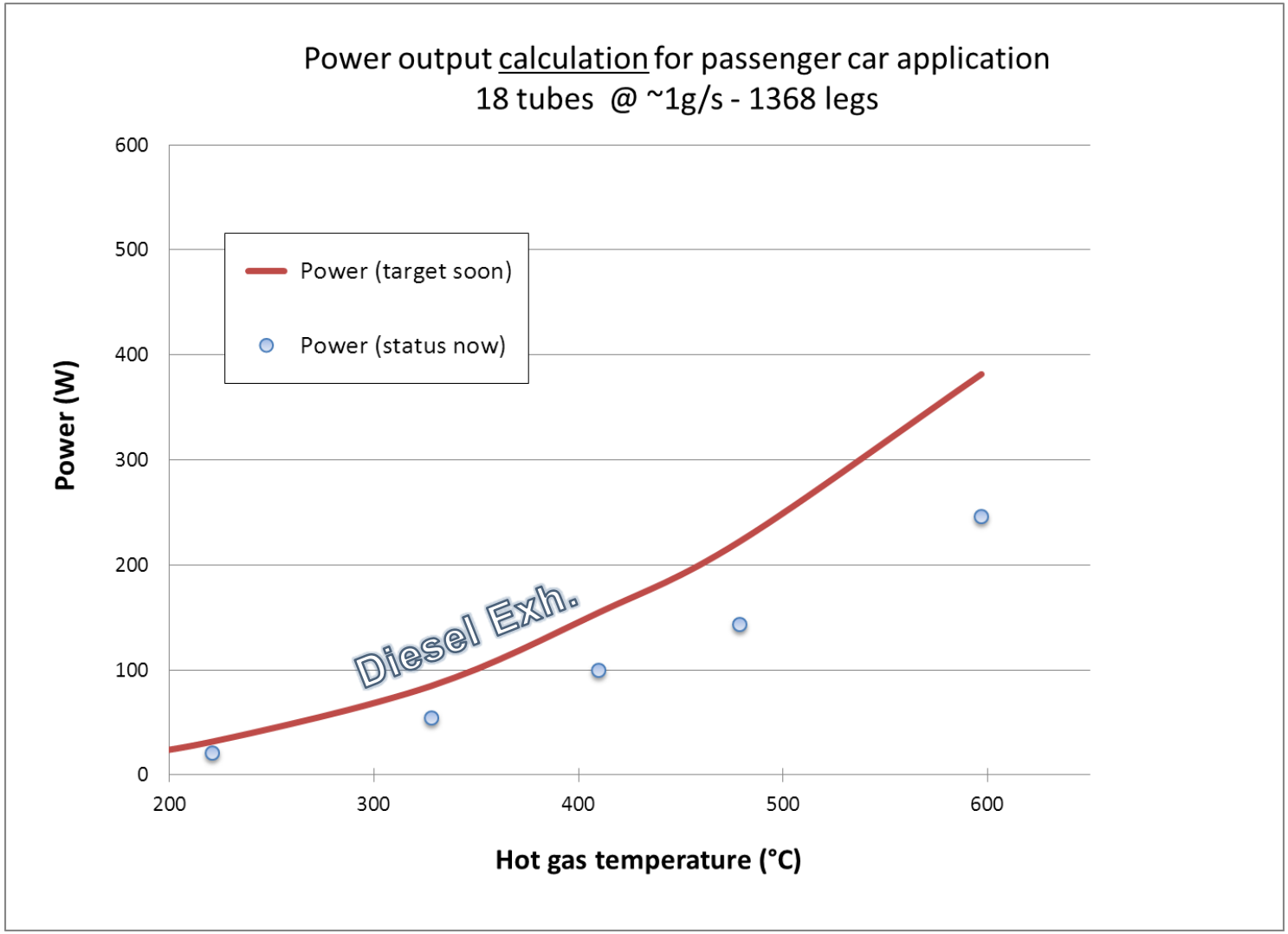


Note: U_0(600°C)=580mV

5) Simulation and testing ΔP<30mbar



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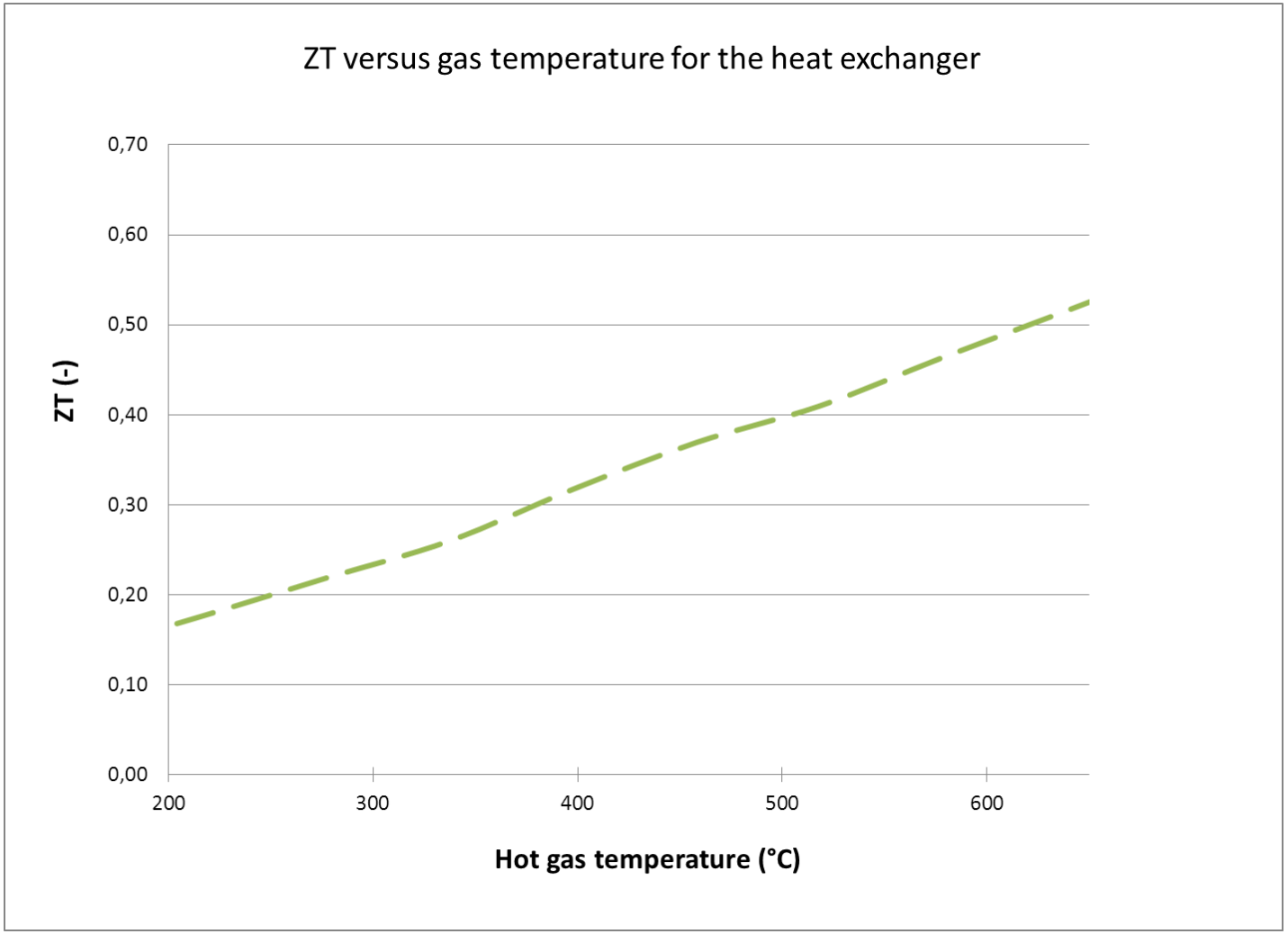


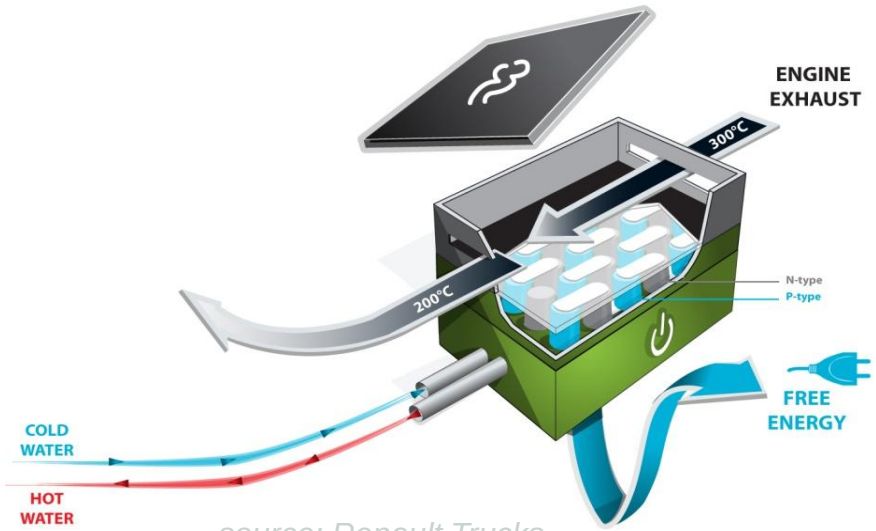
5) Simulation and testing

- Diesel : **50We**-**100We** NEDC, **80We**-**160We** on customer cycle
- Gasoline: **250We**-**500We** on customer cycle

- **400We**-**800We** on cruise point (50% load)

6) Conclusions

- Materials:
  - Alternatives to Pb/Te
  - “Reasonable” cost
  - Higher ZT needed ~200°C
  - Good Mg_2Si type P required



source: Renault Trucks

- Performance:
  - Benefits of direct integration
  - Issue with low voltage / high current
  - Power below pay-off level

- Material improvement & research should continue if we want a mass market application

Acknowledgments

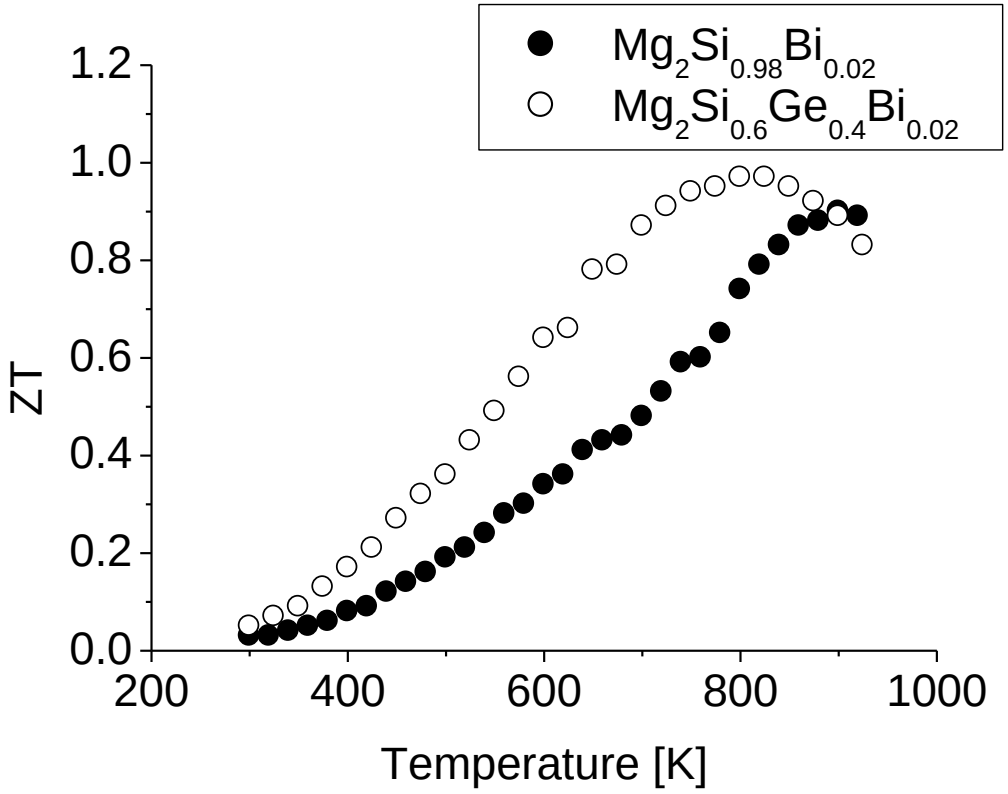
RENOTER project team

DGIS (*Direction Générale de la Compétitivité, de l'Industrie et des Services*)

Région Basse-Normandie

Back-up slides

Back-up slide on n-Mg_2Si (Germanium doping)



Specifications for diesel engine (passenger car)

Specifications for diesel engine			
	Avg. Temperature	Avg. flow	TEG Power (Target)
NEDC	165 °C	12 g/s	100 W
Constant speed 100 km/h	**328 °C**	**25 g/s**	**300 W**
Constant speed 120 km/h	398 °C	53 g/s	500 W