Solid State Vehicular Generators and HVAC Development

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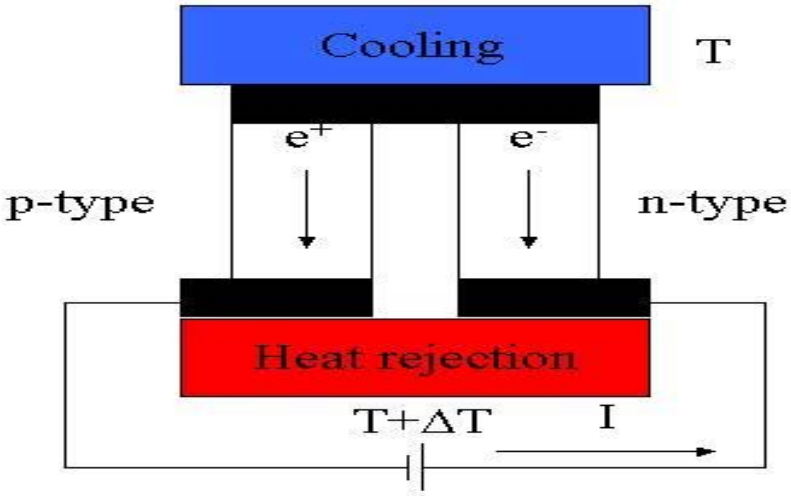
DOE Vehicular Thermoelectric Generator Projects

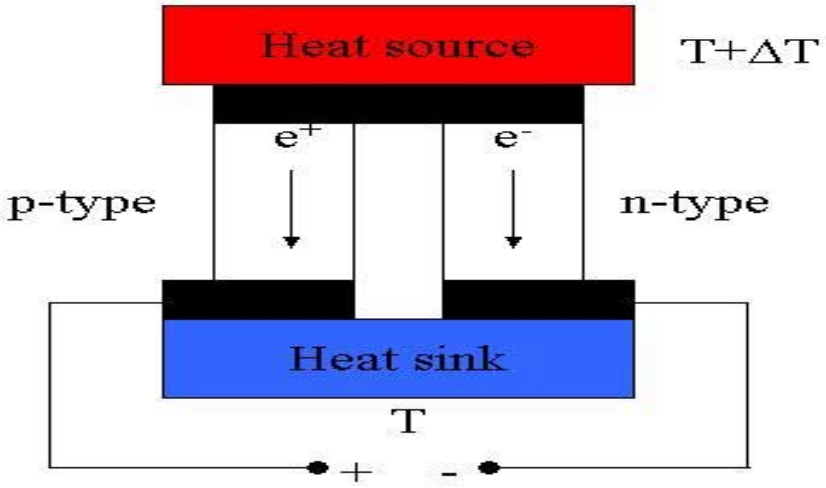
Competitive Award Selections
(March 2004 RFP)

Awardees	Additional Team Members
High Efficiency Thermoelectric	
General Motor Corporation and General Electric	University of Michigan, University of South Florida, Oak Ridge National Laboratory, and RTI International
BSST, LLC.	Visteon, BMW-NA, Ford
Michigan State University	NASA Jet Propulsion Laboratory Cummins Engine Company Tellurex, Iowa State

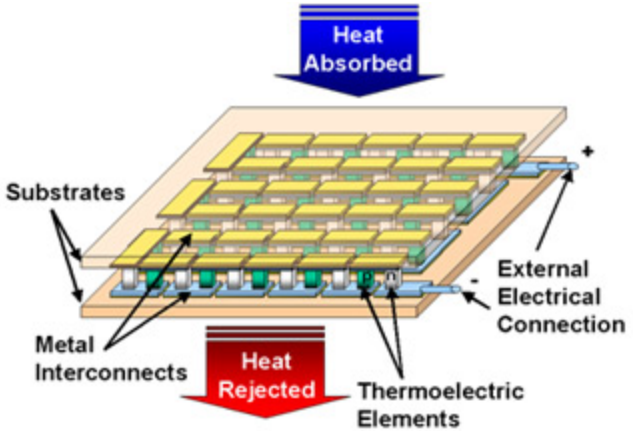
Thermoelectric Modules



Refrigeration



Power generation



TE materials performance: Figure of Merit (ZT)

Electrical conductivity

Seebeck coefficient or thermopower ($\Delta V/\Delta T$)

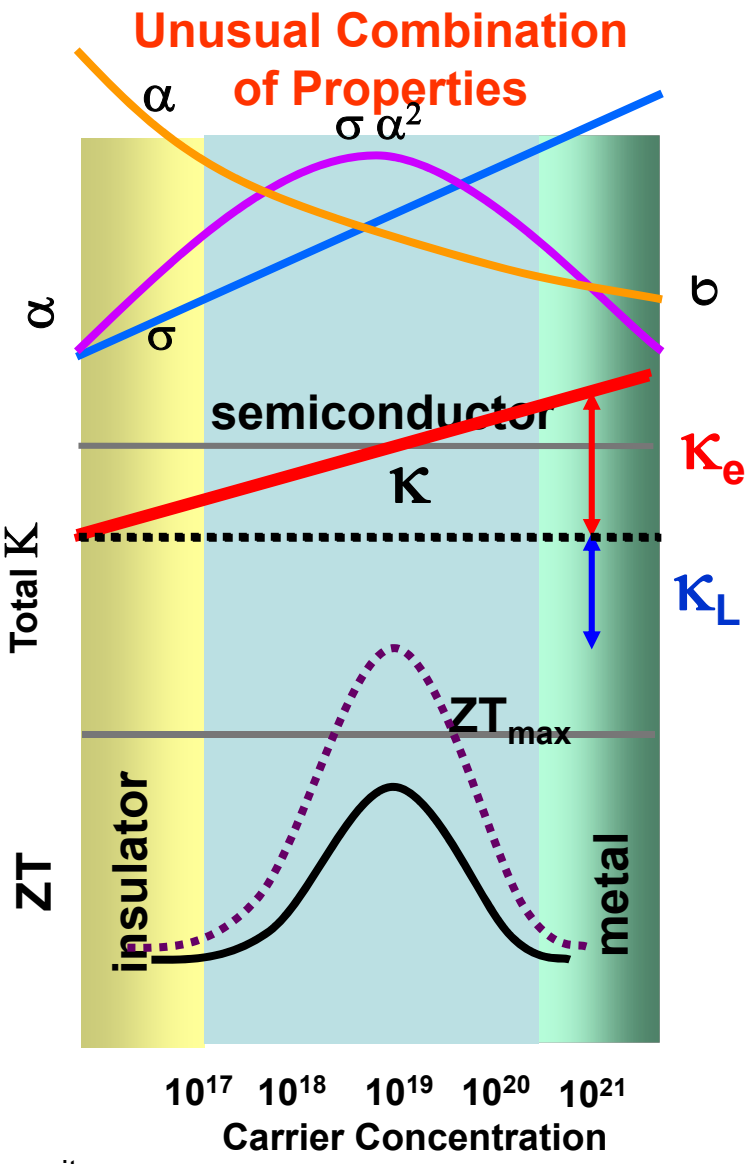
$$ZT = \frac{\sigma \alpha^2}{(\kappa_e + \kappa_L)} \bullet T$$

Total thermal conductivity

$\sigma\alpha^2$ = **Power Factor**

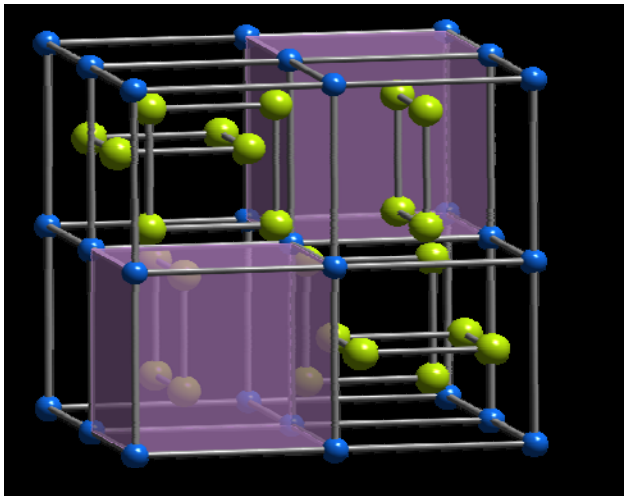
$\sigma = 1/\rho$ = **electrical conductivity**

ρ = **electrical resistivity**

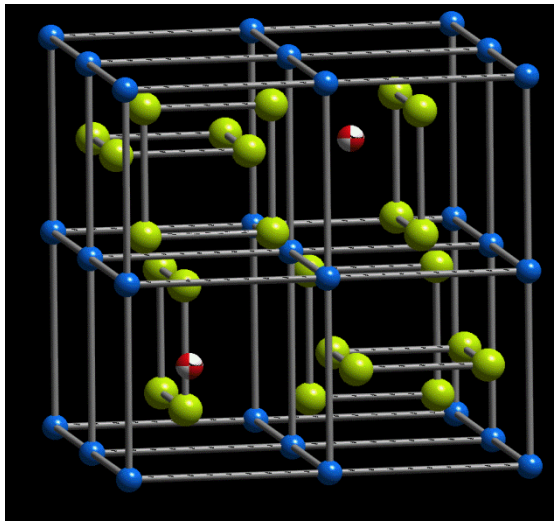


Slide courtesy of Oregon State University

Crystal Structure of Skutterudites



$CoSb_3$ $[Co_8(Sb_4)_6]$



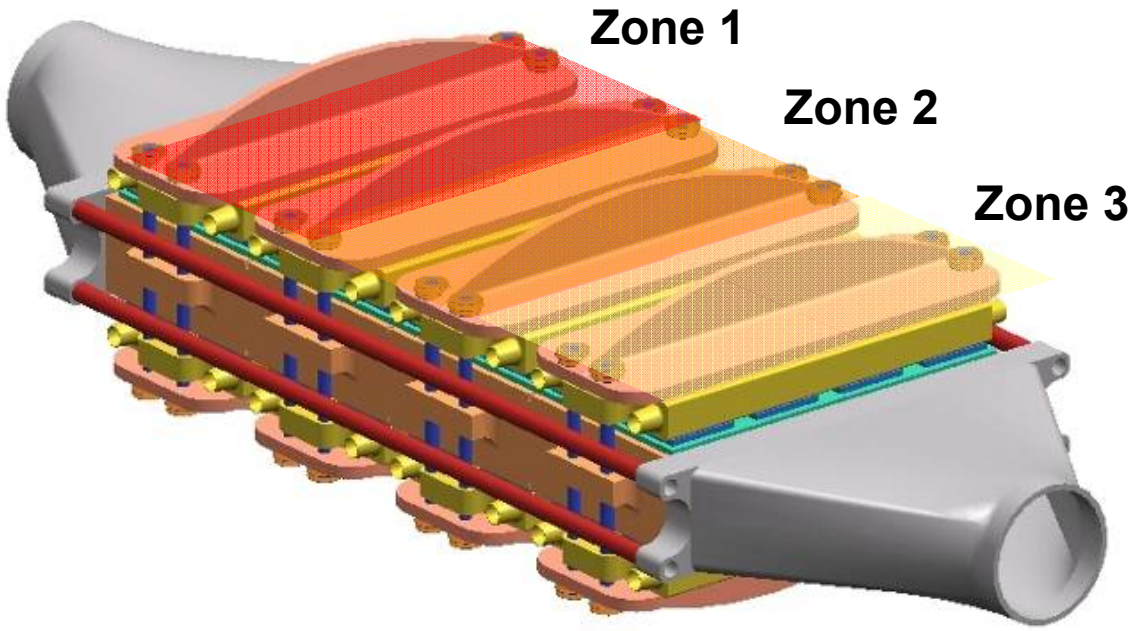
R_xCoSb_3

- Cobalt atoms form a *fcc* cubic lattice
- Antimony atoms are arranged as a square planar rings
- There are 8 spaces for the Sb_4 units
- 6 are filled and 2 are empty

Atoms can be inserted into empty sites. Atoms can "rattle" in these sites – scatter phonons and lower the lattice thermal conductivity.

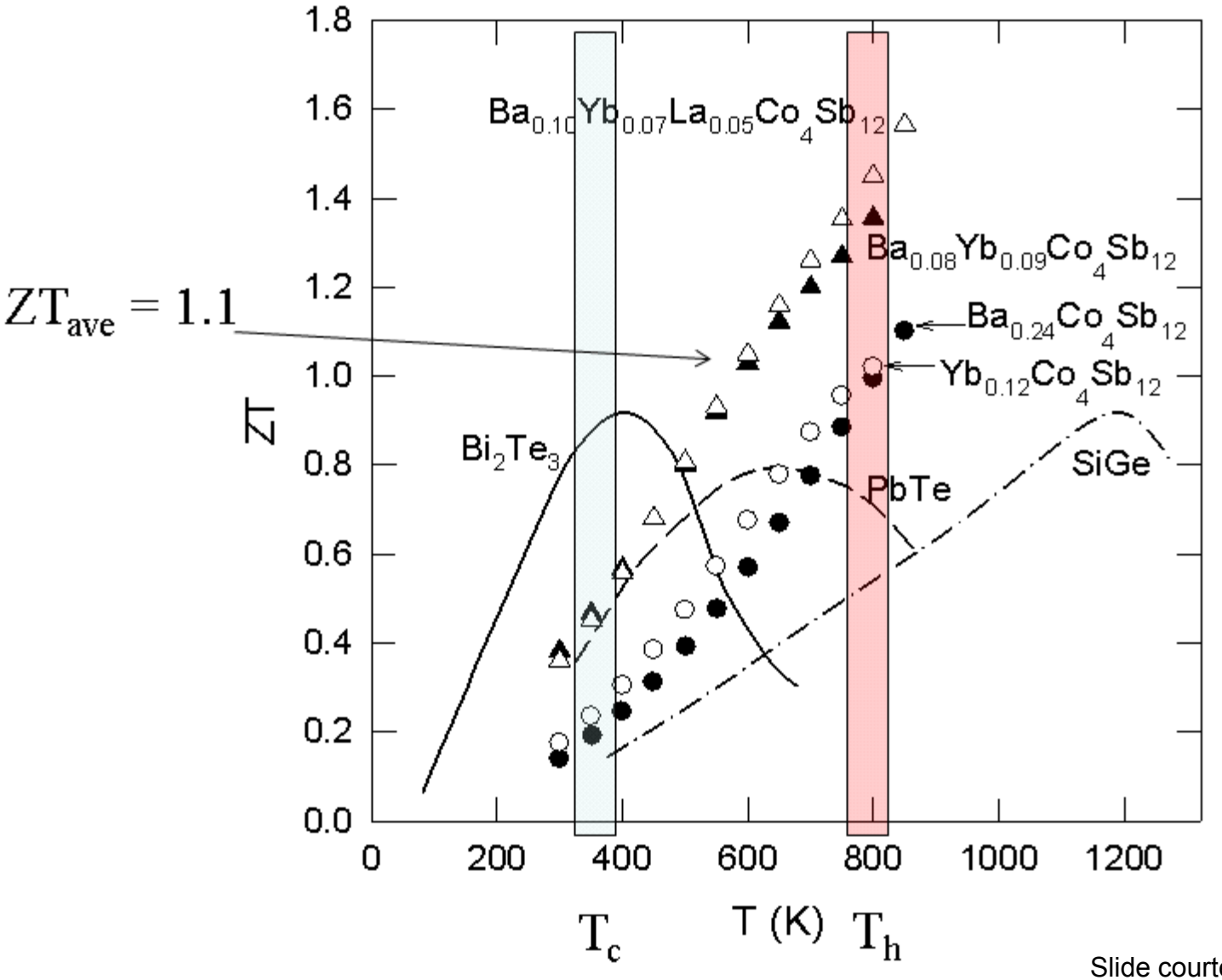
Slide courtesy of Oregon State University

Thermoelectric Modules optimized for Thermal Zones



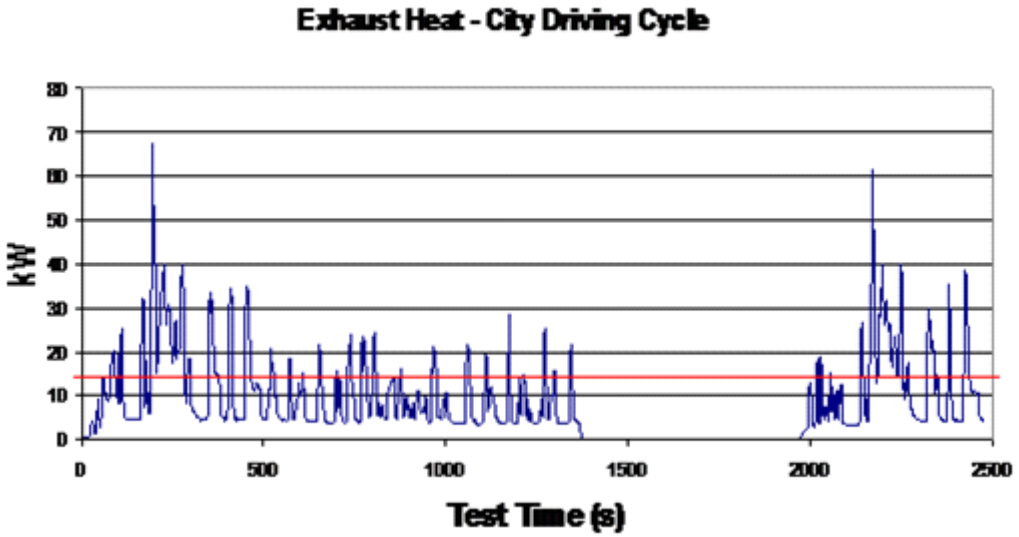
Slide courtesy of General Motors

Highest ZT Achieved in Triple-filled Skutterudites



Slide courtesy of General Motors

GM's Thermoelectric Generator Vehicle: Chevy Suburban

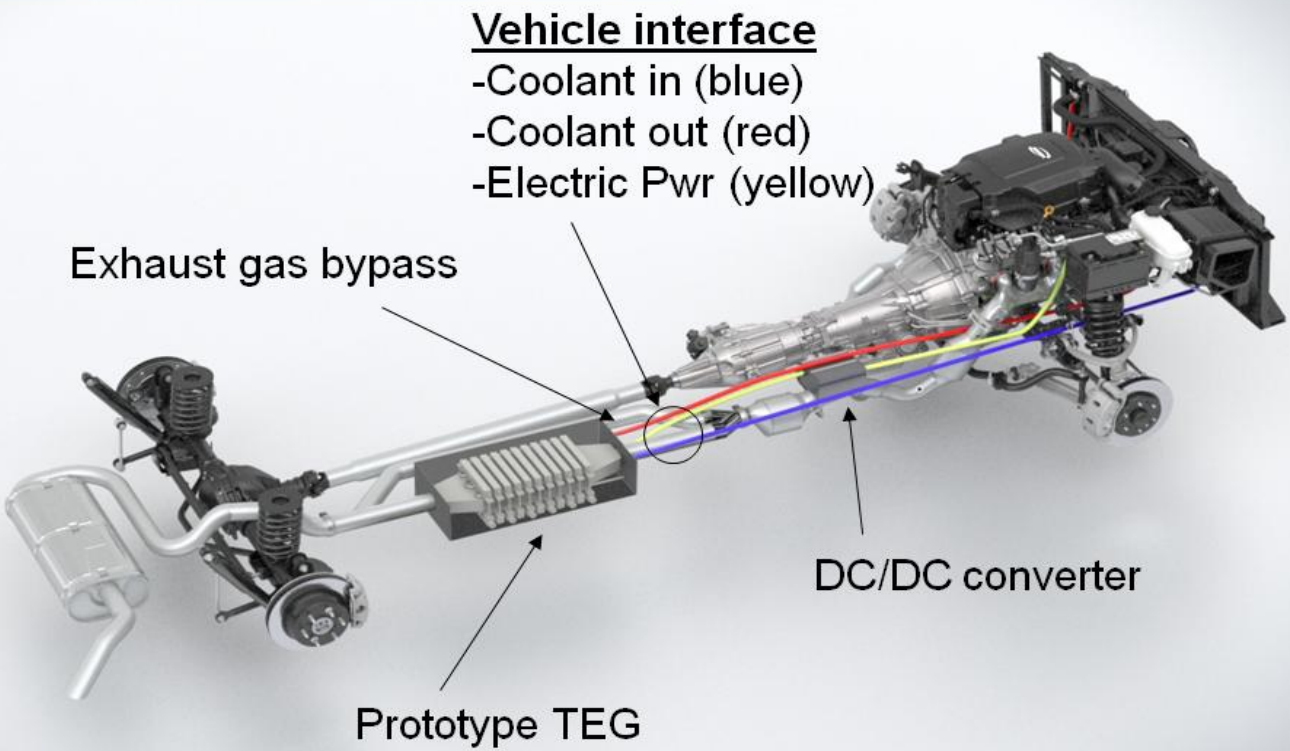


- **plenty of space and waste heat**

Slide courtesy of General Motors

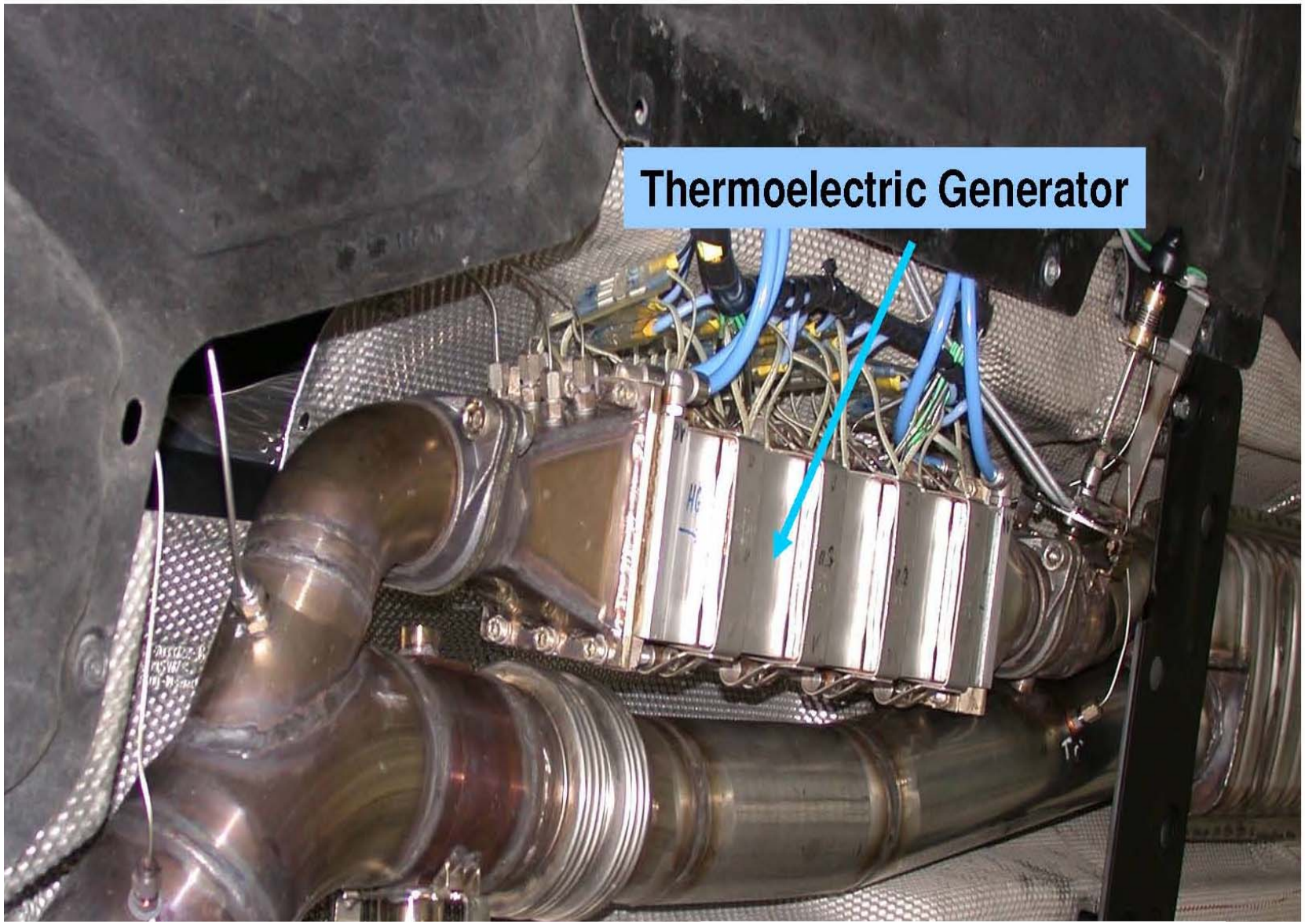
GM TE Generator on a Chevy Suburban

TEG installed in a rear drive vehicle.
GM Suburban



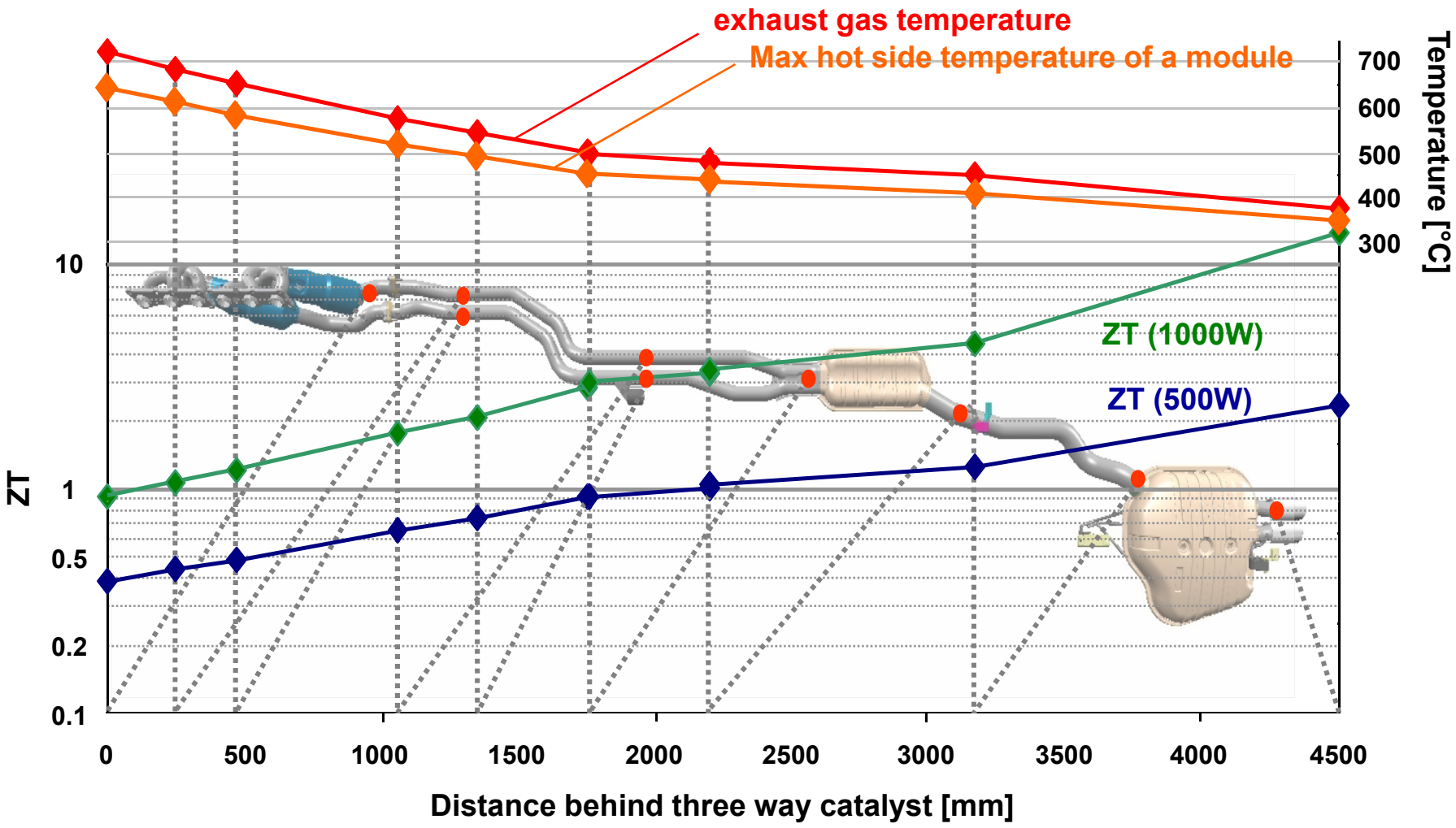
Slide courtesy of General Motors Corp.

TEG Installed in BMW Series 5 Test Vehicle



Courtesy of BSST

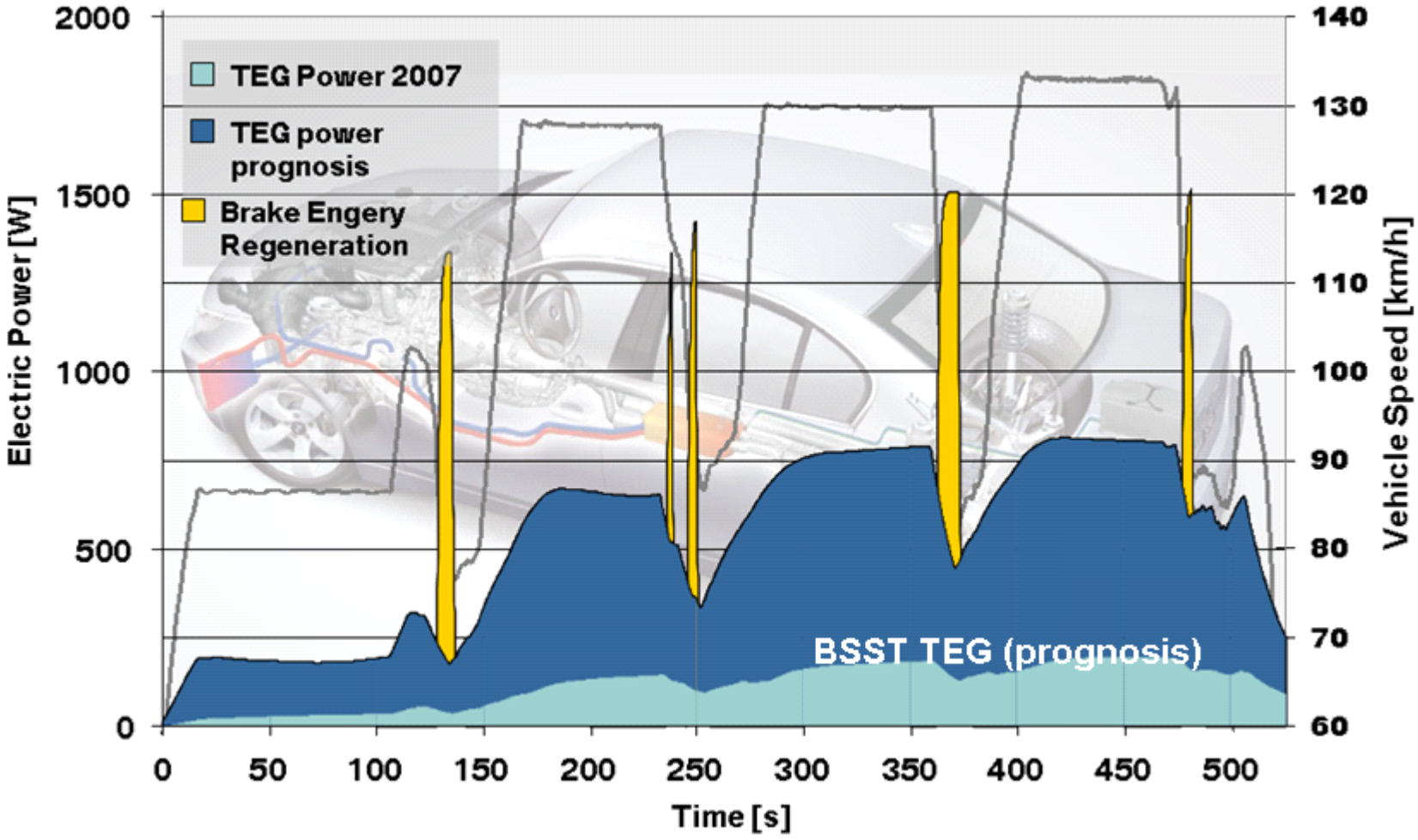
TEG SI Engine Waste Heat Recovery. Need High ZT Material & By-pass



Vehicle 530iA at 130 km/h, Exhaust gas back pressure limited to 30mbar at 130km/h

Slide courtesy of BSST

TEG is ideally compatible with Regenerative Braking



Slide courtesy of BSST

Thermoelectric Waste Heat Recovery. BMW Sedans

Slide courtesy of BSST

Zonal HVAC System Concept

Zonal TE devices located in the dashboard, headliner, A&B pillars and seats / seatbacks

Slide courtesy of BSST

COP Calculations – Traditional PTC in an EV Plus Enhanced CCS + Zonal Devices

Heating to driver = 500W

Total PTC heating to vehicle = 1200W

PTC COP = 1

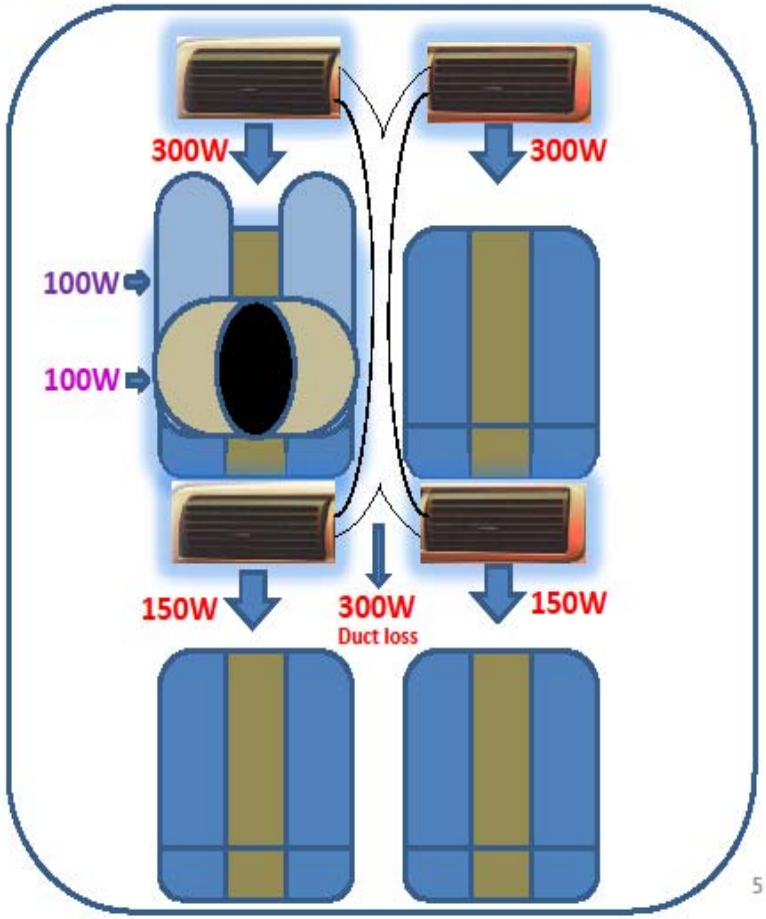
CCS heating to driver = 100W

CCS COP = 2.5

Zonal TED heating to driver = 100W

Zonal TED COP = 2.5

Total power used = 1280W



BSST

Slide courtesy of BSST

COP Calculations – TE Central HVAC in an EV + Enhanced CCS + Zonal Devices

Heating to driver = 500W

Total TE central HVAC heating to vehicle = 1200W

TE central HVAC COP = 2.5 (assumed)

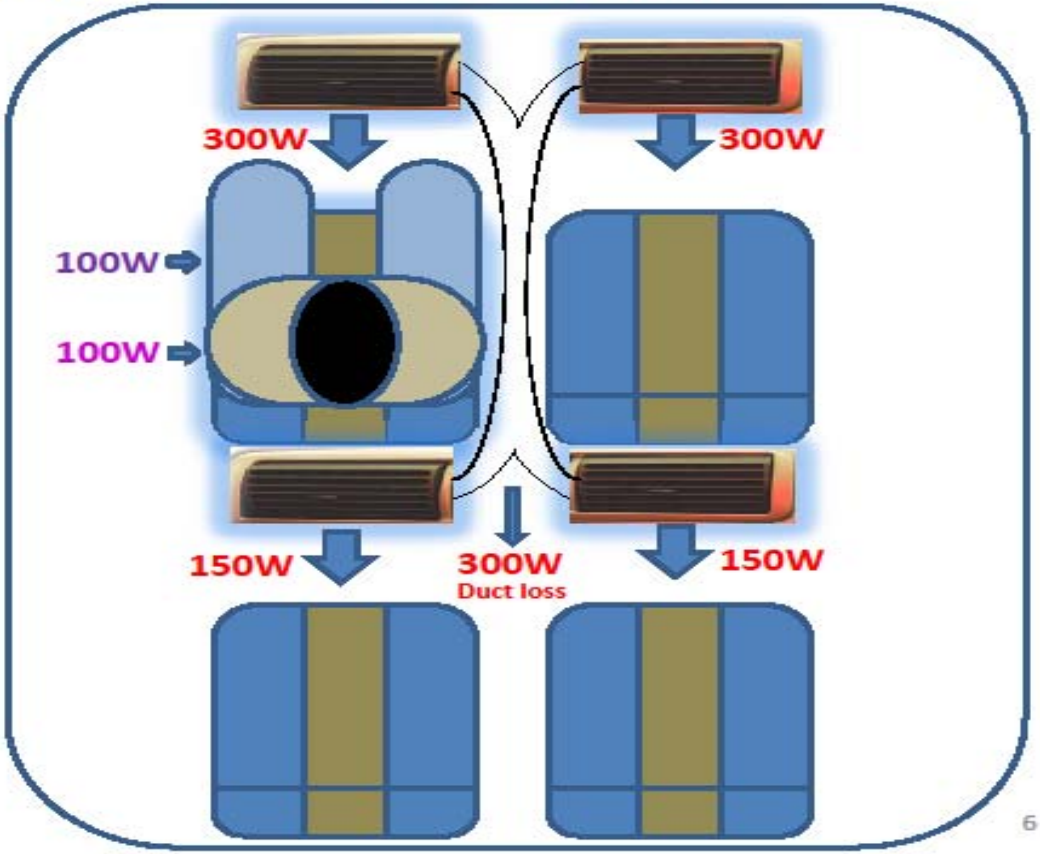
CCS heating to driver = 100W

CCS COP = 2.5 (assumed)

Zonal TED heating to driver = 100W

Zonal TED COP = 2.5 (assumed)

Total power used = 560W



BSST

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TE applications: heat recovery from exhausted gases

CRF CENTRO RICERCHE FIAT

Reduced Energy Consumption by Massive Thermoelectric Waste Heat Recovery in Light Duty Trucks

HeatReCar - EU project

SEVENTH FRAMEWORK PROGRAMME

SIEMENS	Siemens - Germany
ROM INNOVATION	ROM Innovation -France
CRF CENTRO RICERCHE FIAT	CRF - Italy
BOSCH	Bosch - Germany
Termo-Gen AB	Termo-gen AB - Sweden
Fraunhofer IPM	Fraunhofer IPM - Germany
Valeo	Valeo - France

Slide courtesy of Fiat

TE applications: distributed energy generation

CENTRO RICERCHE FIAT

Thermoelectricity for Mobile Systems

THERMOBILE - *under evaluation*

CNRS	CNRS – France
CRF CENTRO RICERCHE FIAT	CRF – Italy
SNCF	SNCF – France
CEA	CEA – France
EMPA	EMPA – Switzerland
DTU	DTU – Denmark
BOSCH	BOSCH – Germany
Termo-Gen AB	Termo-Gen – Sweden
BASF	BASF - Germany

Slide courtesy of Fiat


Thank
You!