



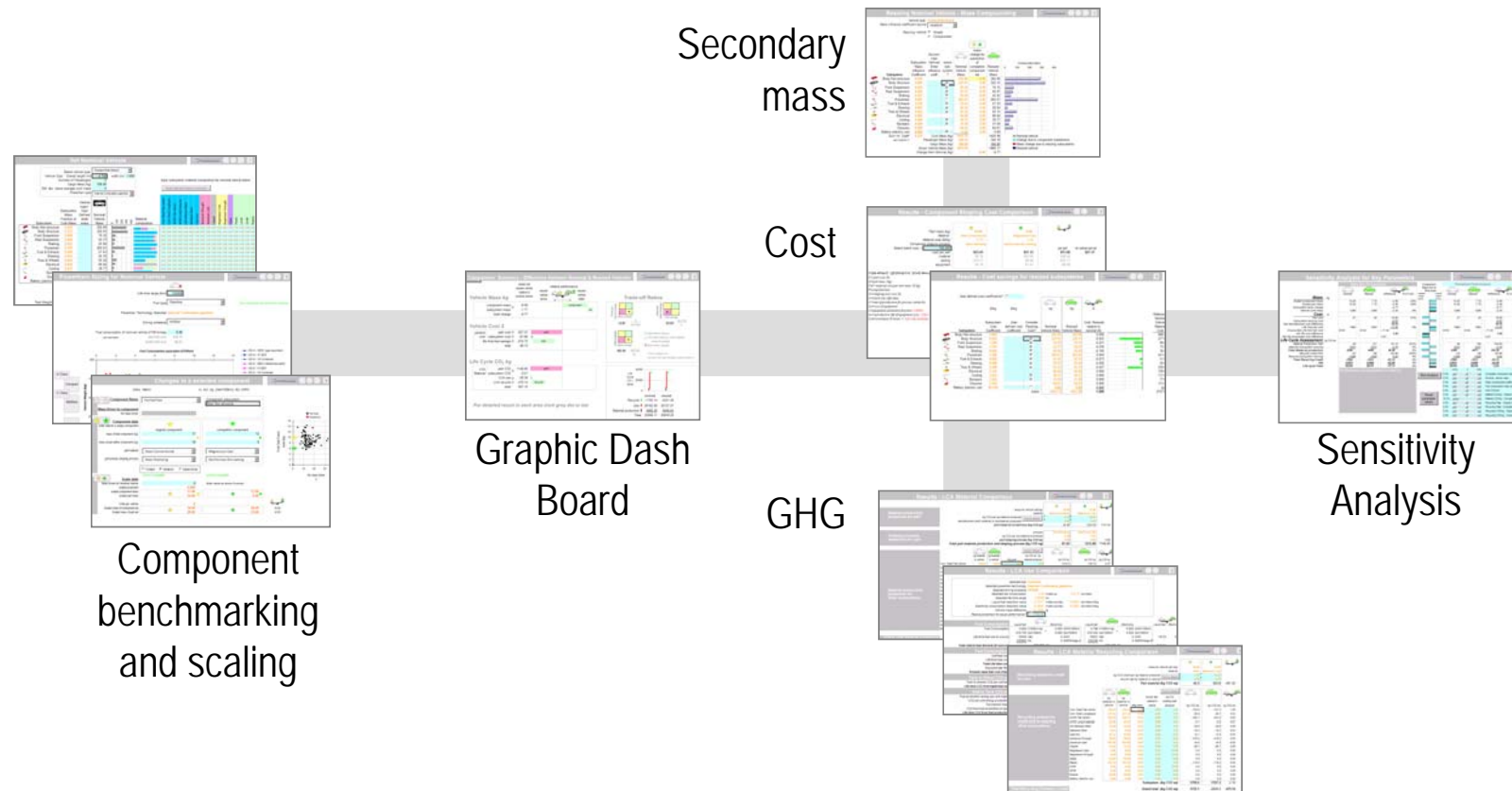
# Design Advisor Workshop

*Donald E Malen  
University of Michigan*



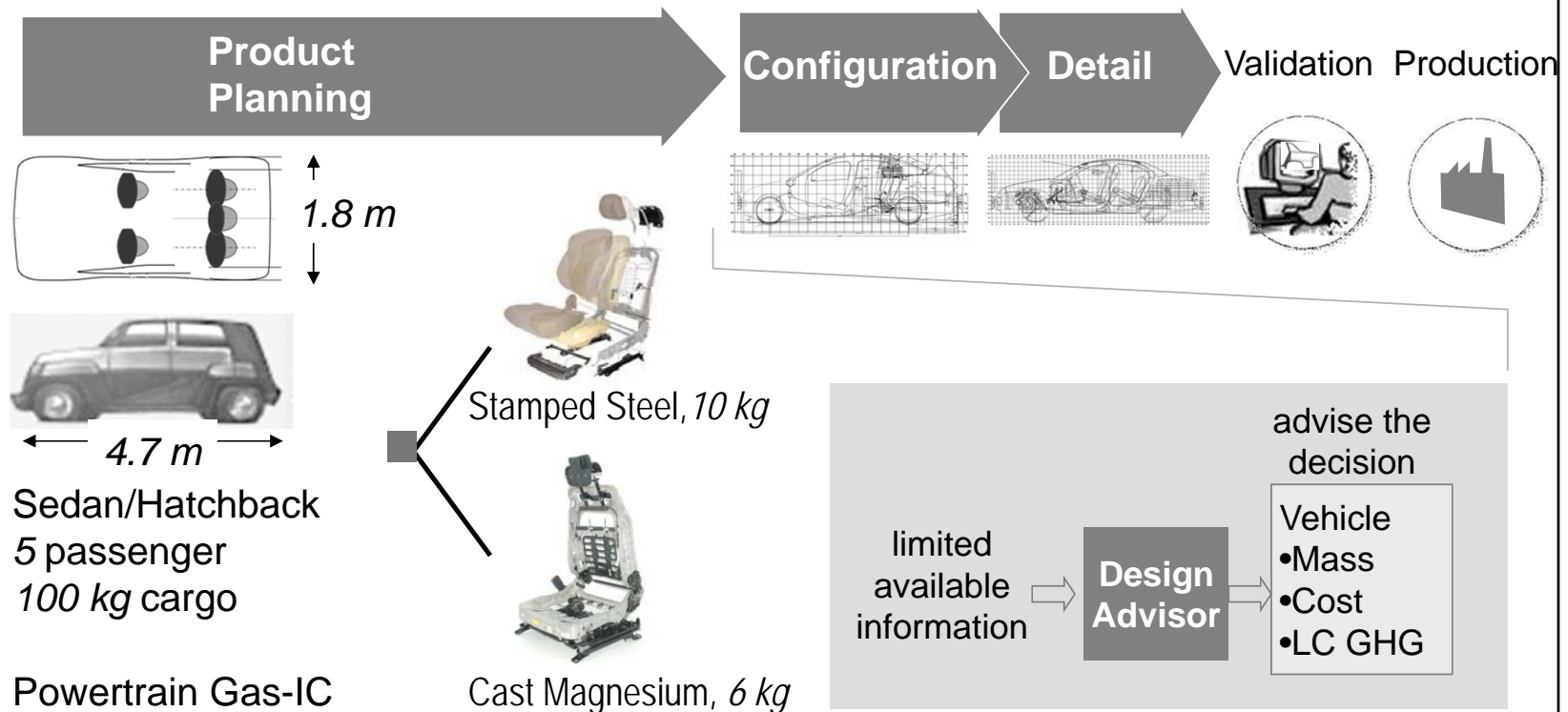
# Design Advisor

***Design Advisor- Excel Workbook to support material selection decisions***

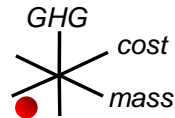


# Advising a Material Selection Decision

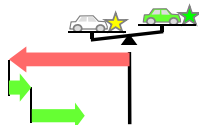
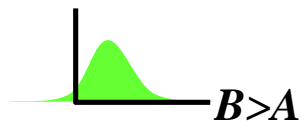
*Material selection decisions often occur early in the design process*



## Design Advisor – Purpose



component	vehicle
-component mass	-Length, Width
-material	-passengers, cargo
-manufacturing	-Powertrain type
	-Fuel type



- **Multiple Metrics**  
*Mass including subsystem resizing*  
*Cost*  
*Life Cycle GHG*
- **Use information available during preliminary design**  
*<5 pieces of info about each component*  
*<7 pieces of info about vehicle*  
*Parameters for models are pre-loaded*
- **Very quick analysis time**  
*<5 minutes data entry*  
*<30 seconds for computations*
- **Accuracy sufficient for A-B comparison**  
*Uses rigorous analytical models*
- **Graphic display to promote What-if studies and understanding of trade-offs**

## Design Advisor Workshop - Objectives

- 1. Gain ability to use Design Advisor***
- 2. Understand the models used and their limitations***
- 3. Examine some trade-offs in material selection***

## Design Advisor Workshop - Agenda

### 4. Cost estimation

*Hatchback door-a*

### 3 Secondary Mass estimation

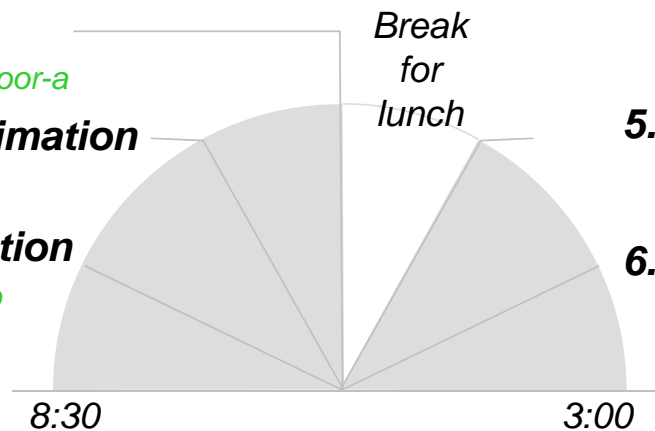
*Hood*

### 2 Vehicle mass estimation

*Seat frame-b*

### 1. Intro & guided case study

*Seat frame-a*



### 5. Powertrain sizing

*Hatchback door-c*

### 6. LCA & Sensitivity study

*Advance BOM*  
*Hood Sensitivity*

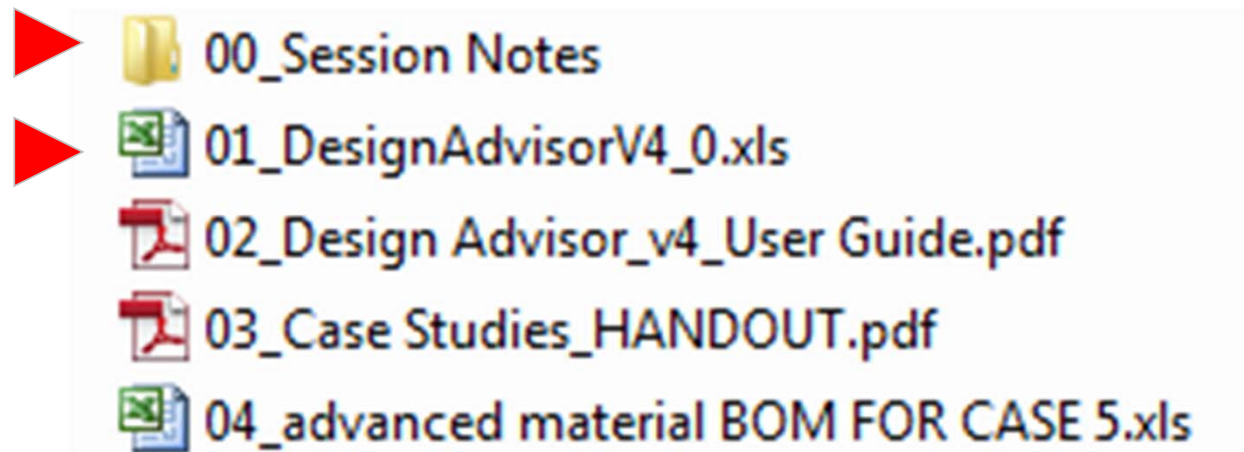


# **Design Advisor Workshop**

## **Session 1**

### **Guided Case Study**

## Design Advisor Workshop Files





## Careful

***Design Advisor*** is written in Excel 97-2003 format (.xls).

It contains macros which must be enabled.

If you are using Excel 2007 or later, you must be careful to:

1. Enable MACROS
2. Save to the correct format.



**SAVING AS AN .XLSX or .XLSM FORMAT WILL  
PREVENT THE MACROS FROM FUNCTIONING**



## To open the *Design Advisor* and enable macro content

Double click on *Design Advisor* Excel file icon.

After *Design Advisor* opens in Excel, you should see a message at the center top of the screen:

**Security Warning** Some active content has been disabled **Options**

Select *Options*, then select *Enable this content*



## To save your work while in Excel

### Method 1

Use Save, and make sure the format is .xls (this will keep the same file name)

### Method 2

Use Save As, and make sure the format is *Excel 97-2003 Workbook (.xls)*. You can change the name using this method.



## Case Study 1

### Component: Seat Frame



#### Original Component

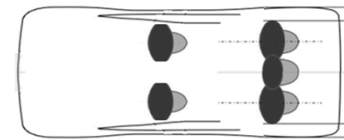
Steel  
Stamped  
17 kg total seat mass  
10 kg frame mass



#### Competitor Component

Magnesium,  
High pressure die cast  
13 kg total seat mass  
6 kg frame mass

### Vehicle Parameters



Sedan/Hatchback  
5 passenger  
100 kg cargo  
OAL=4.7 m  
OAW=1.8 m  
New architecture  
Internal Combustion-gasoline  
Powertrain is fixed and will not change  
6.8 liter/100 km (HYZEM schedule)  
Life time range = 155,000 km

## Definitions



**Component** an assembly

**Part** metallic/composite part or weldment within the component



**Original** component and part



**Competitor** component and part



**Nominal** vehicle

vehicle defined by the user with original component



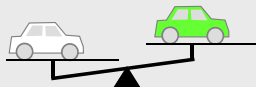
**Resized** vehicle

nominal vehicle with subsystems resized for competitor component

*Mass/Cost/CO<sub>2</sub>*

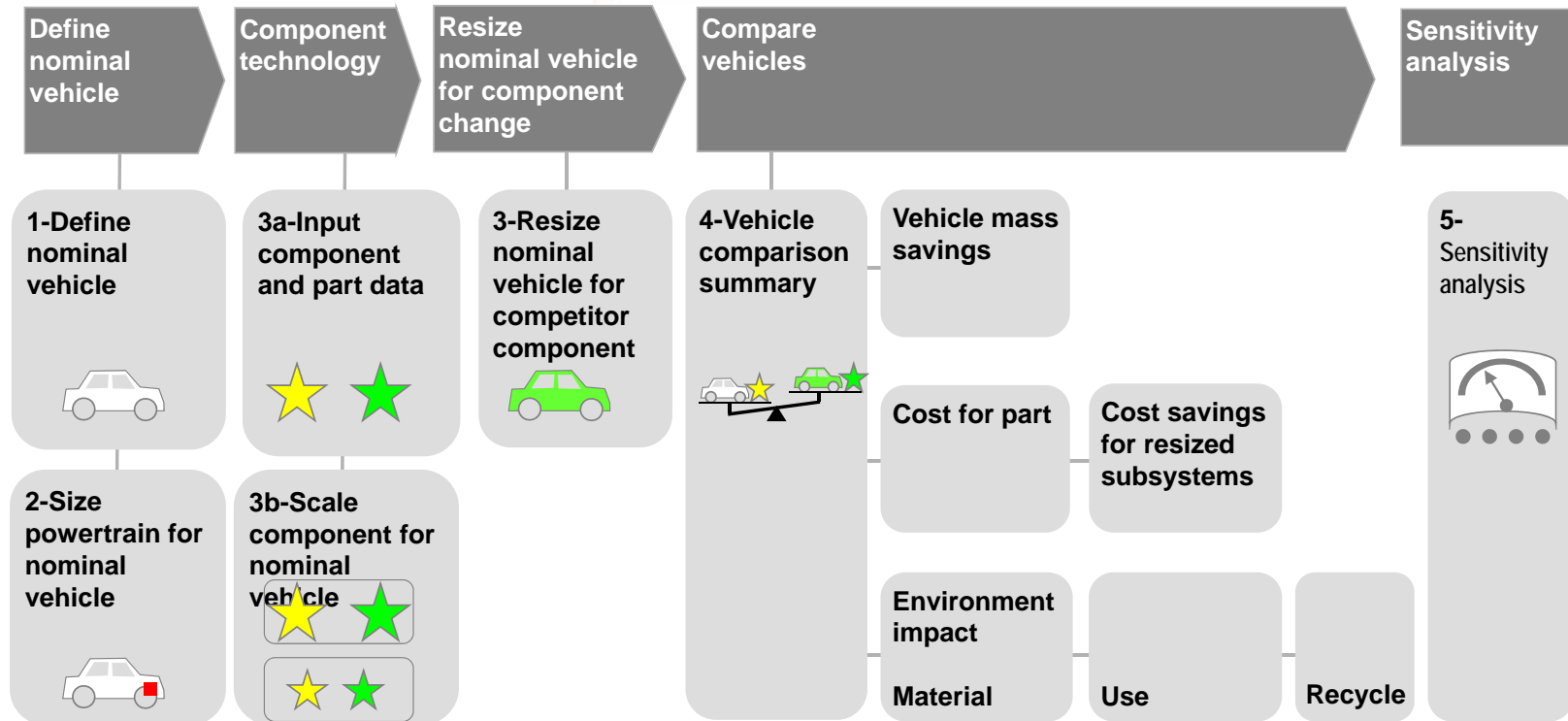


**Changes for Part** (Primary Changes)



**Changes for Vehicle including resizing subsystems**

# Design Advisor Solution Map



Instructions

# Overview of Design Advisor – Protection

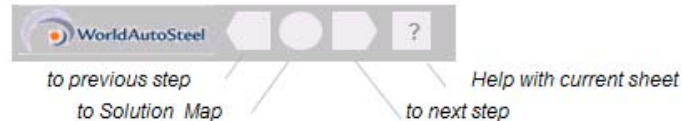
## Instructions


[Return](#)

The purpose of the *Design Advisor* is to assess the impact on the overall vehicle system of a change to a component. Several metrics are calculated in the areas of mass reduction, change in cost, and environmental impact.

The user is stepped through the process of building two vehicles; a nominal vehicle with the original component, and a resized vehicle with the competitor component. The performance of these two vehicles is then compared.


The user can use the *Solution Map* sheet to move through building process from left to right by clicking on the numbered icons, inputting data, then using the *To Solution Map* button found on each sheet. An alternative method is to use the navigation icons at the top of each screen.



The *Results and Sensitivity* sheet displays a comparison of the nominal and resized vehicles using several metrics (mass, cost, CO2). A sensitivity study may be run by varying several key parameters.

The intent of the *Design Advisor* is to provide early guidance in whether to pursue the component technology. The metrics are necessarily approximate and use First Order Analysis, FOA, to make the estimates. If a decision is made to proceed with the technology, follow-up calculations with more precise analysis tools should be used.

Conventions have been adapted to display information:

 Fields marked in light blue indicate information input by the user

Color coding of cells and numbers

 Numbers in orange indicate values calculated in a prior step and carried over for reference.

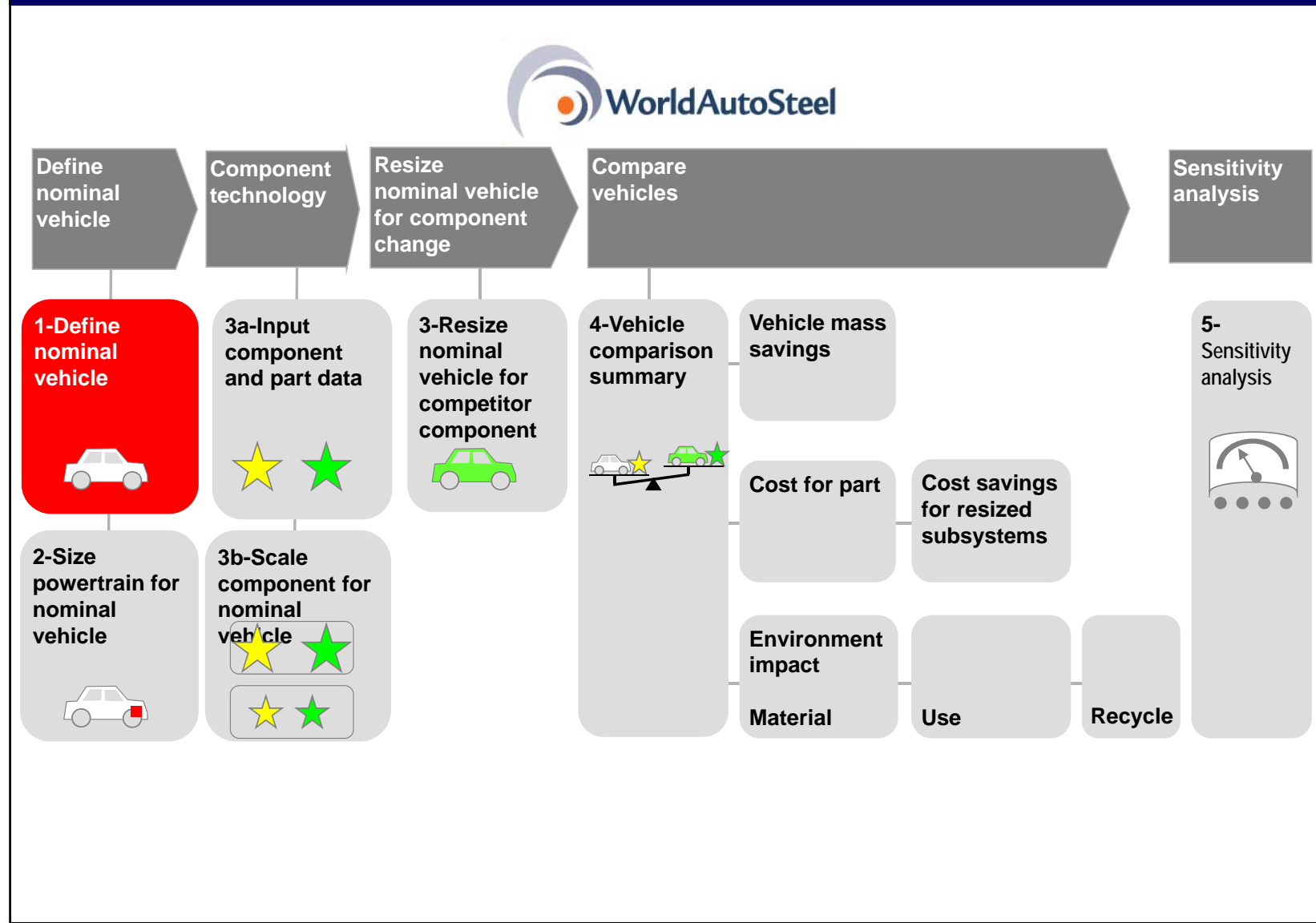
**Variable map**

**Optional information:** The variables and the sheet on which they are introduced are listed under the tab *Variable Map*.

Protection ON

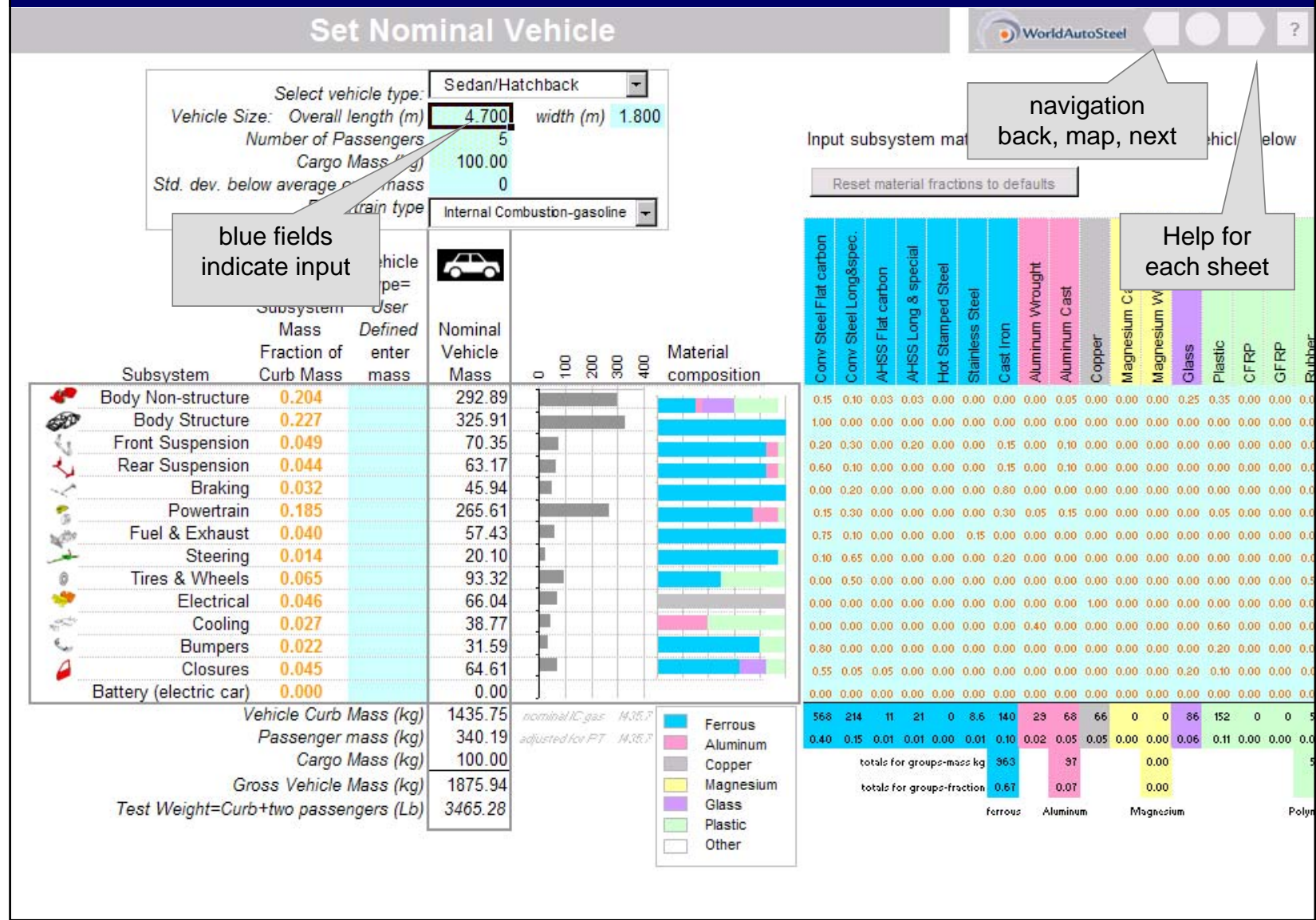
Spreadsheets are protected to avoid accidental changing of cells. Normally leave Protection ON

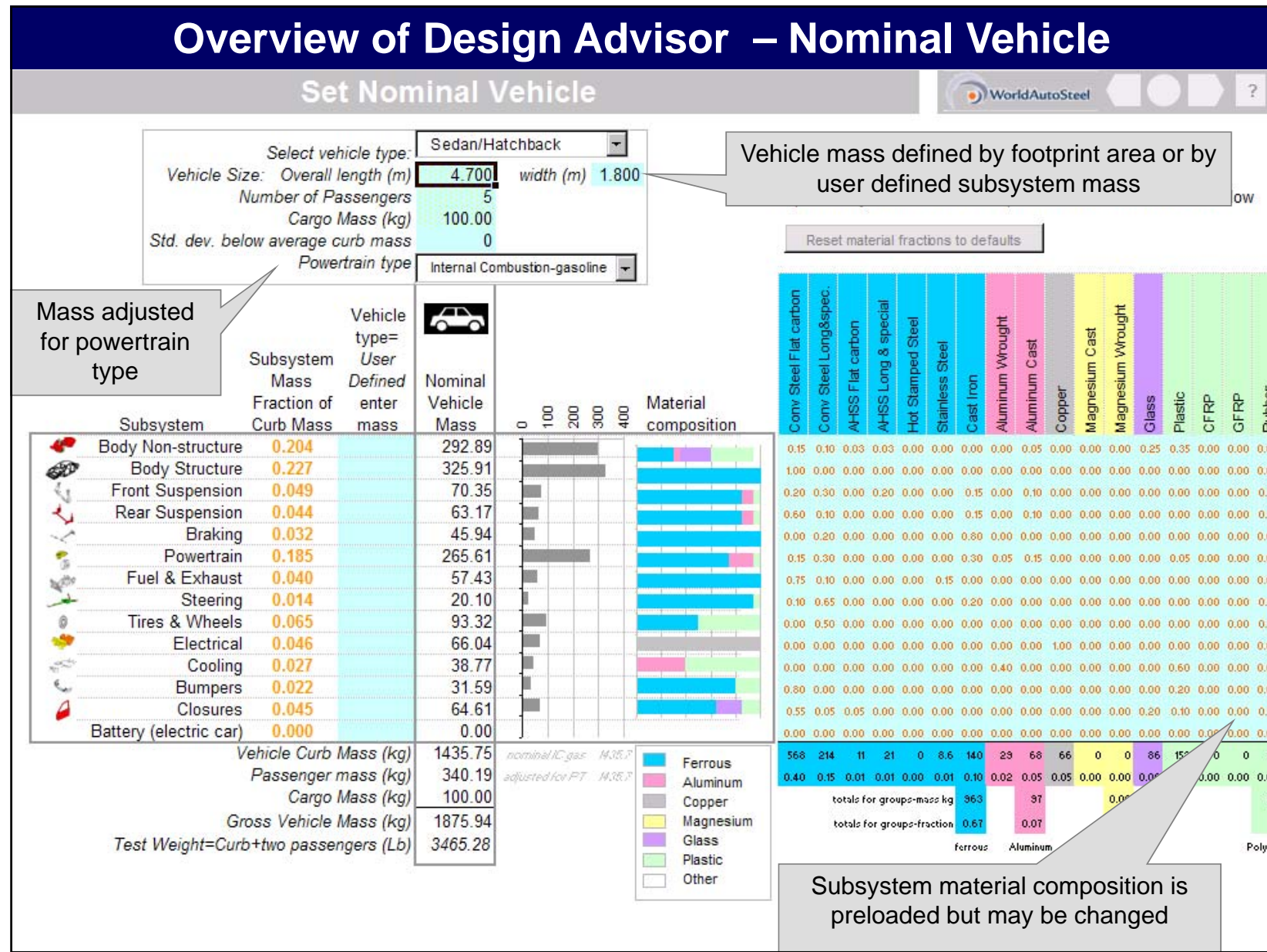
# Design Advisor Solution Map



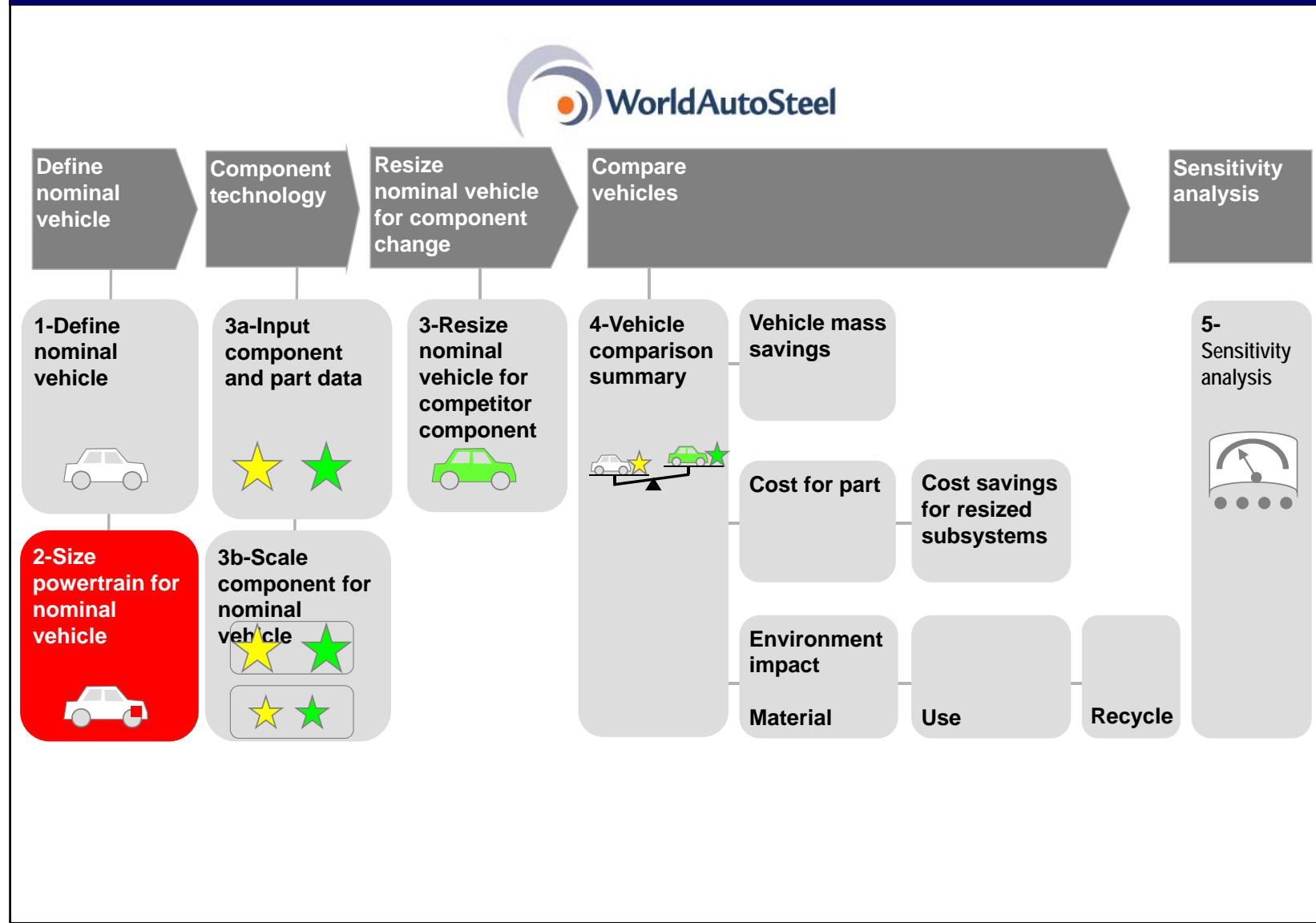


# Overview of Design Advisor – Nominal Vehicle

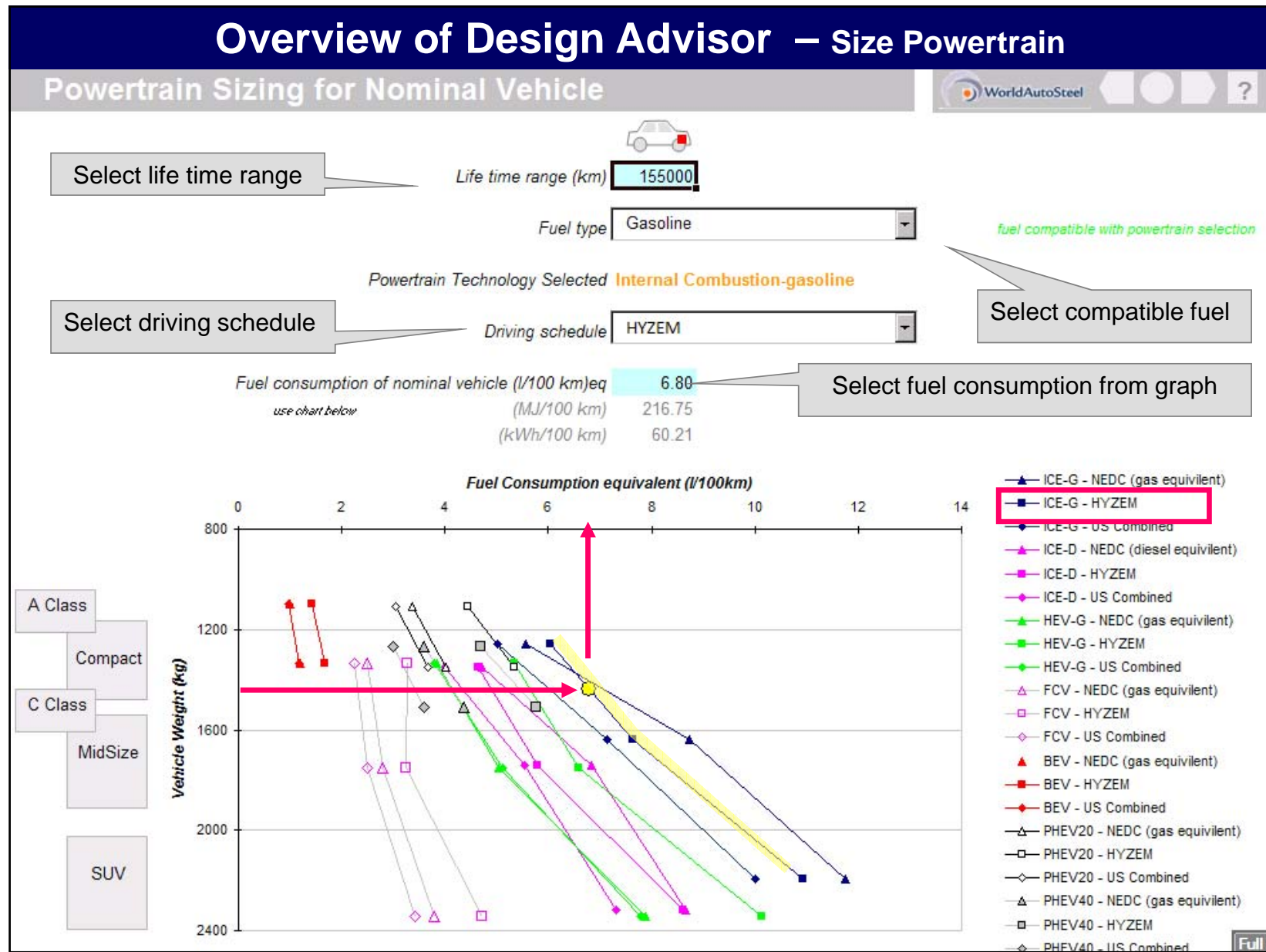


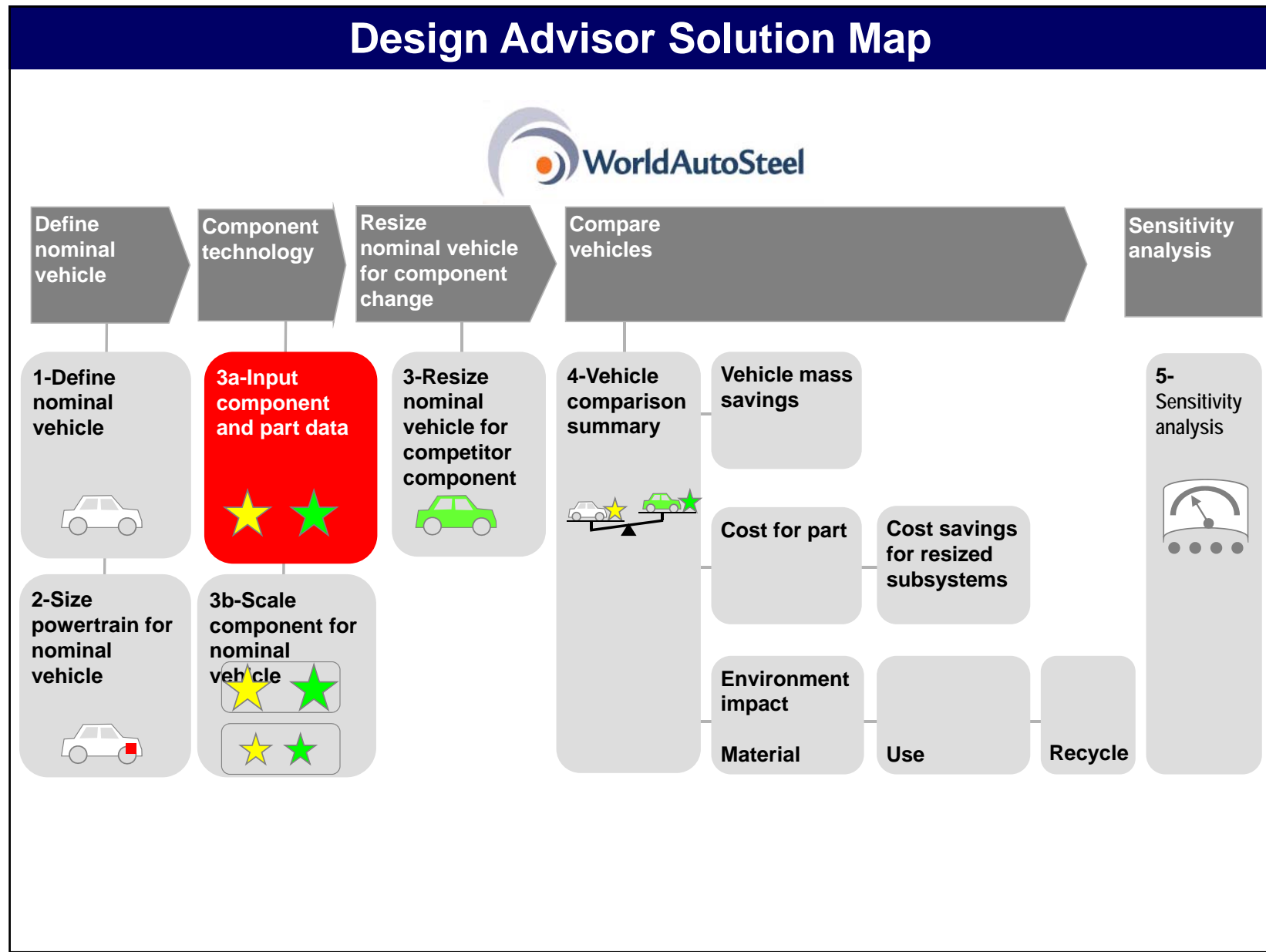


# Design Advisor Solution Map









# Overview of Design Advisor – Input

**Changes to a selected component**

Units: *Metric*      m, km, kg, (liter/100km), MJ, kWh

**Component Name** Front Seat Frame      Component subsystem: Body Non-structure

**Mass Driver for component**  
No mass driver

**Component data**  
enter data for a single component

	★ original component	★ competitor component
mass of total component (kg)	17	13
mass of part within component (kg)	10	6
part material	<span style="border: 1px solid black; padding: 2px;">Steel-Conventional</span>	<span style="border: 1px solid black; padding: 2px;">Magnesium Cast</span>
part primary shaping process	<span style="border: 1px solid black; padding: 2px;">Steel Stamping</span>	<span style="border: 1px solid black; padding: 2px;">NonFerrous Die Casting</span>
	<input type="radio"/> Folded <input checked="" type="radio"/> Shallow <input type="radio"/> Deep Draw	

*process compatible*      *process compatible*

**Scale data**  
Mass driver for Nominal Vehicle

scaling exponent	0
scaled component mass	7.00
scaled part mass	0.00
Units per vehicle	2
Scaled mass of component set	34.00
Scaled mass of part set	20.00

*Enter some as above if unknown*

**Complexity for stampings**

**Confirmation that material and process are compatible**

**Material and Process Lists:**

- Steel-Conventional
- Steel-AHSS
- Steel-Hot Stamped
- Steel-Stainless
- Cast Iron
- Aluminum Wrought
- Aluminum Cast
- Magnesium Wrought
- Magnesium Cast
- CFRP
- GFRP
- SMC

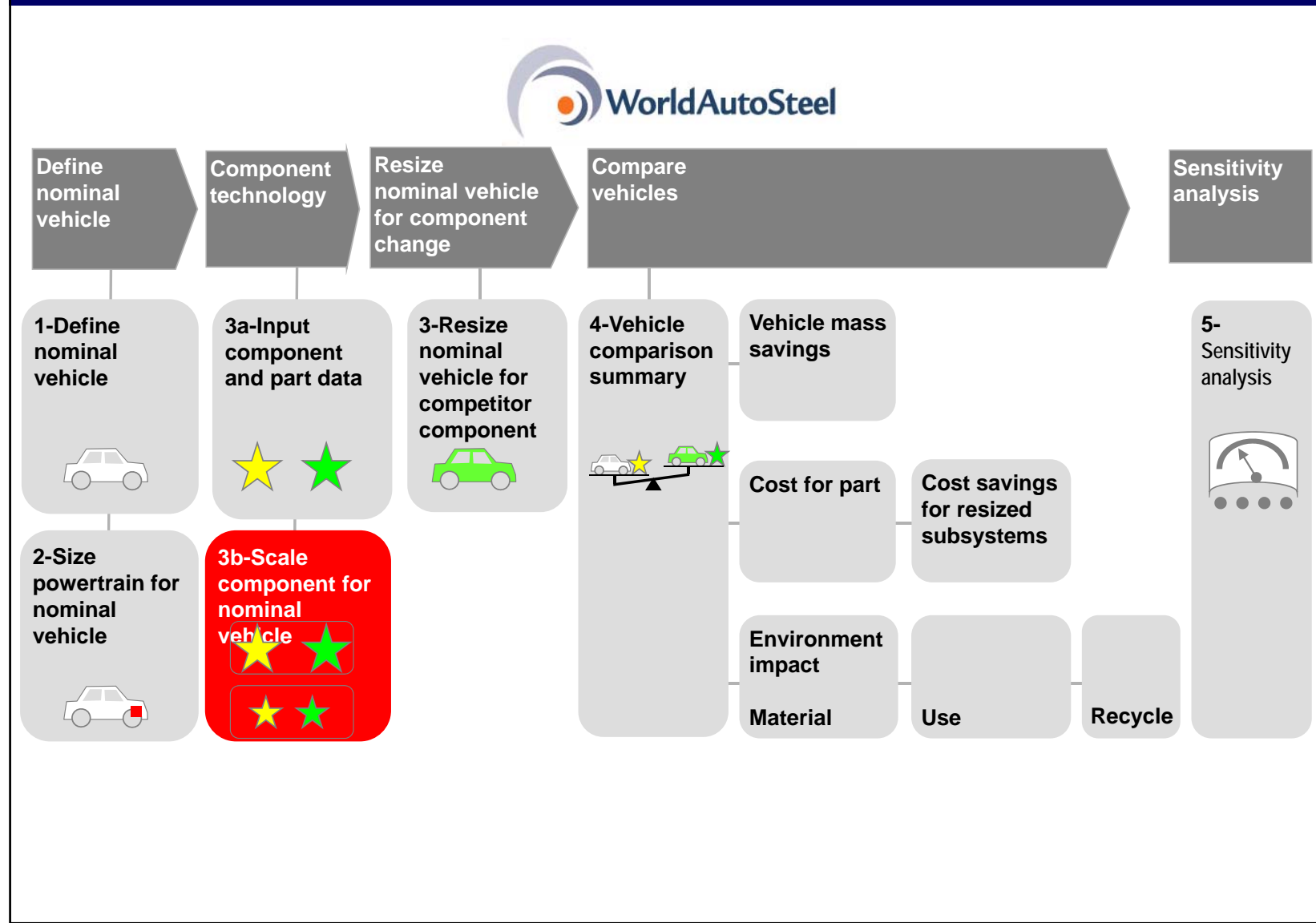
**Process Lists:**

- Steel Stamping
- Steel TWB Stamping
- Steel Hot Stamping
- Steel open roll form
- Steel Tube Hydroform
- Steel Forging
- Iron Casting
- Nonferrous Stamping
- Nonferrous Extrusion
- Nonferrous Die Casting
- Nonferrous Forging
- Composite SMC
- Composite Resin Transfer

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Full

# Design Advisor Solution Map



# Overview of Design Advisor – Resizing Component for Nominal Vehicle

**Changes to a selected component**

Units: *Metric* *m, km, kg, (liter/100km), MJ, kWhr*

**Component Name** Front Seat Frame Component subsystem: *Body Non-structure*

**Mass Driver for component**  
No mass driver

**Component data**  
enter data for a single component

	original component	competitor component
mass of total component (kg)	17	13
mass of part within component (kg)	10	6
part material	Steel-Conventional	Magnesium Cast
part primary shaping process	Steel Stamping	NonFerrous Die Casting
<input type="radio"/> Folded <input checked="" type="radio"/> Shallow <input type="radio"/> Deep Draw		
<i>process compatible</i> <i>process compatible</i>		

**Scale data**  
Mass driver for Nominal Vehicle: 0 *Enter same as above if unknown*

	original component	competitor component
scaling exponent	0.000	13.00
scaled component mass	17.00	6.00
scaled part mass	10.00	12.00
Units per vehicle	2	
Scaled mass of component set	34.00	26.00
Scaled mass of part set	20.00	12.00

**Benchmark plot**

Front Seat Frame mass (kg)

Legend: ■ Ferrous, ■ Aluminum

Mass driver

ability to resize component based on mass driver

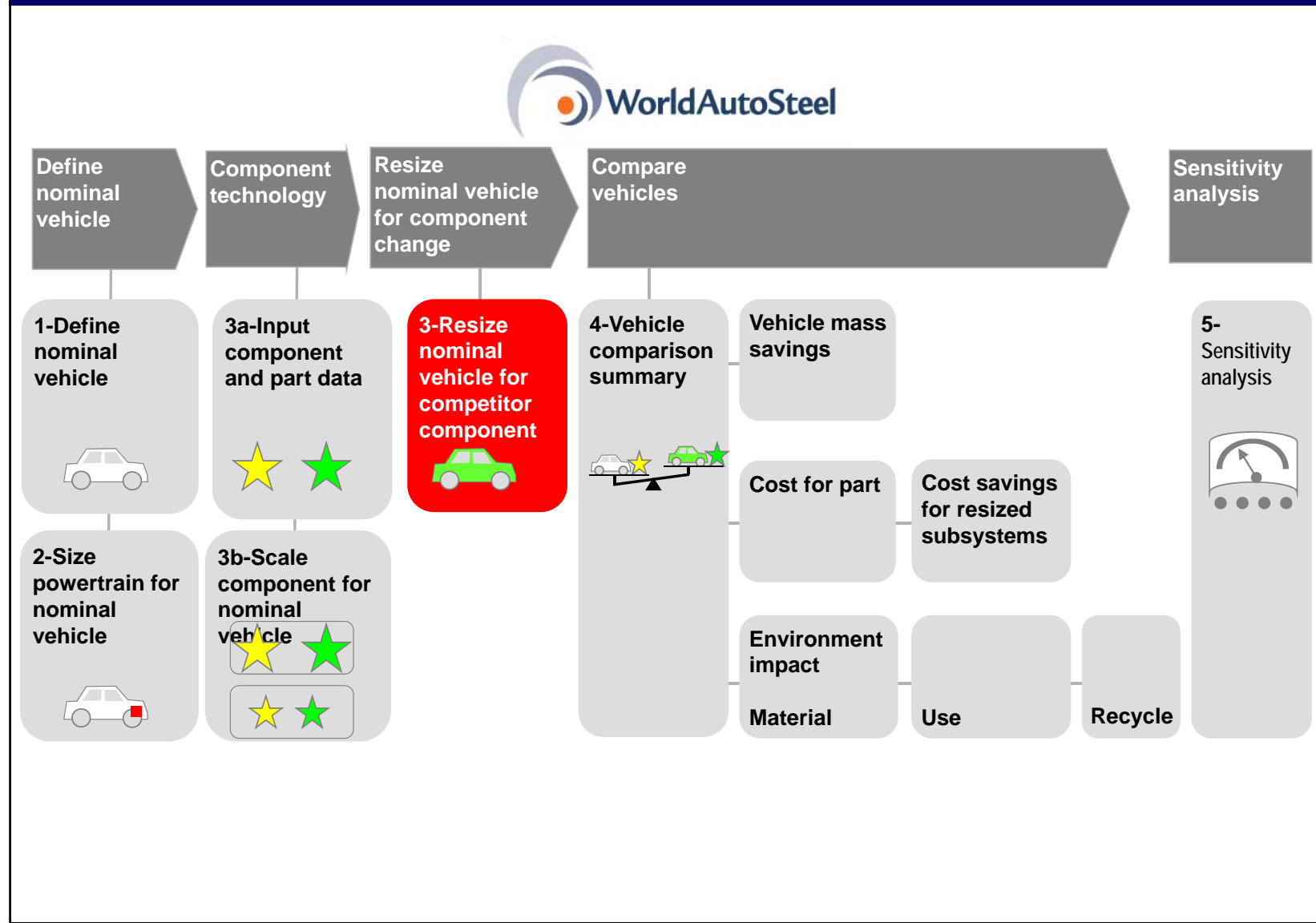
exponent for resizing

WorldAutoSteel

Full

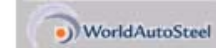


# Design Advisor Solution Map



# Overview of Design Advisor – Resize Nominal Vehicle

## Resizing Nominal Vehicle - Mass Compounding



Vehicle type: **Sedan/Hatchback**

Mass influence coefficient source: **Analytical**

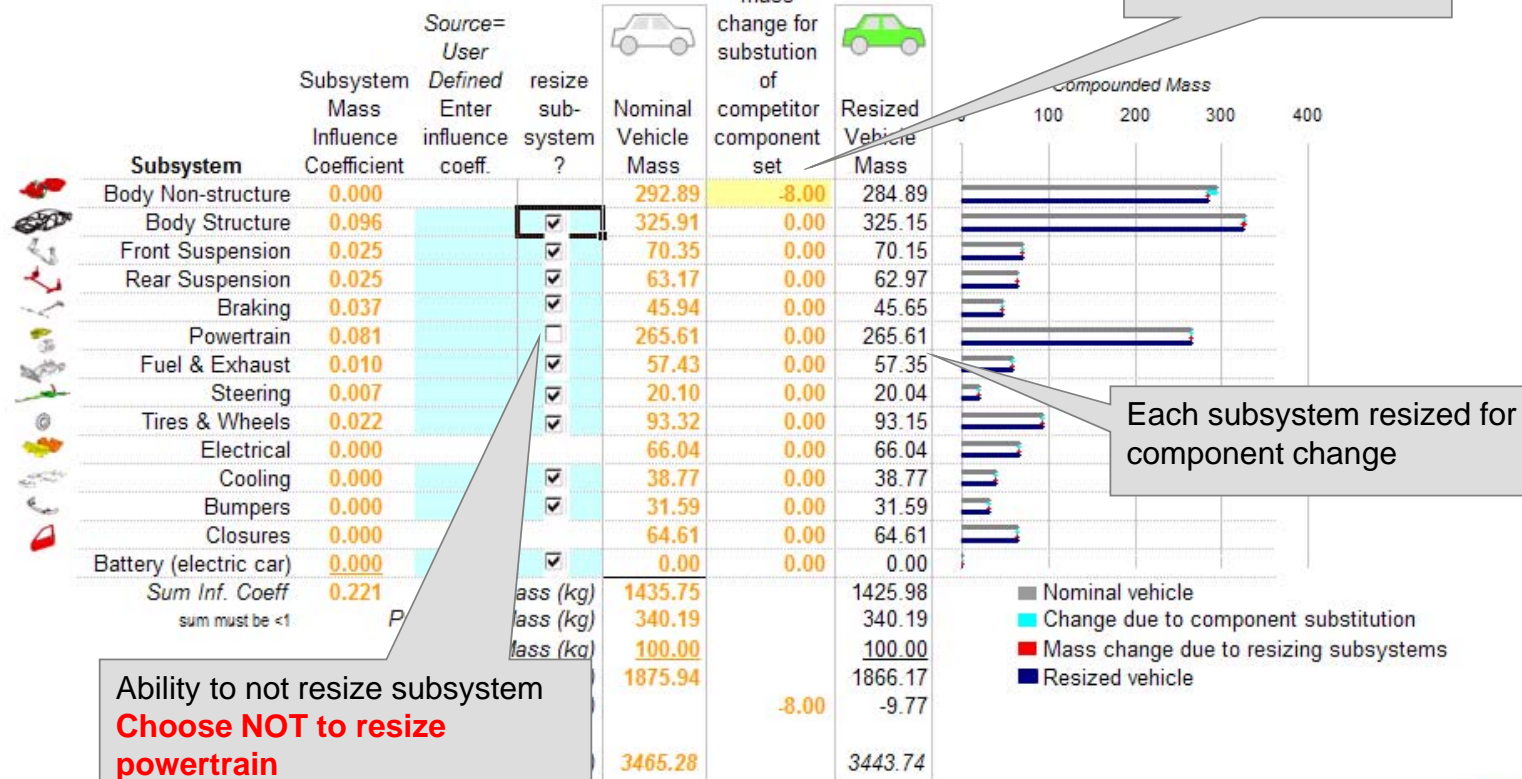
Resizing method: ☒ Simple  
☐ Compounded

Choose secondary mass resizing method



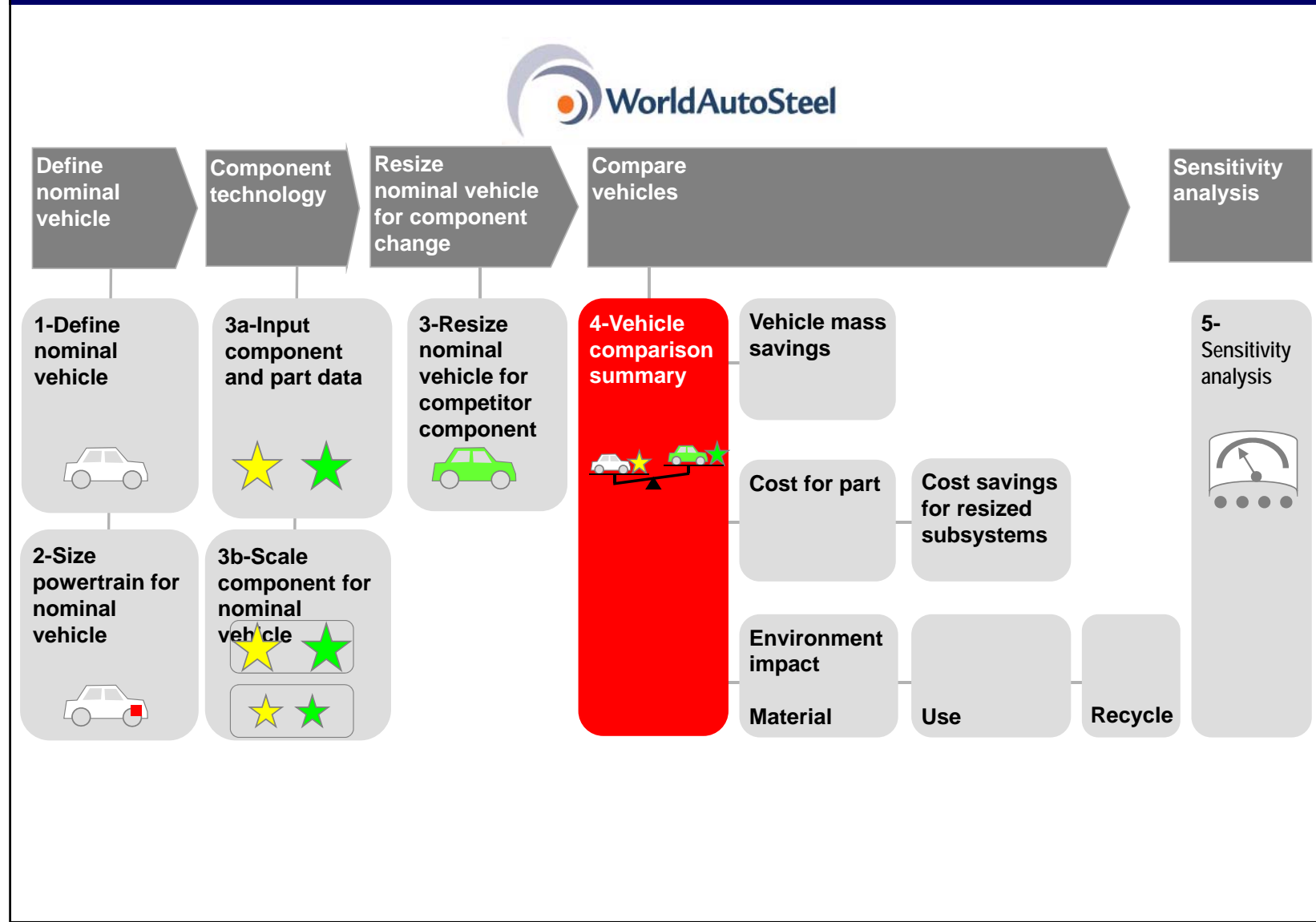
mass change for substitution of competitor component set

mass change due to component



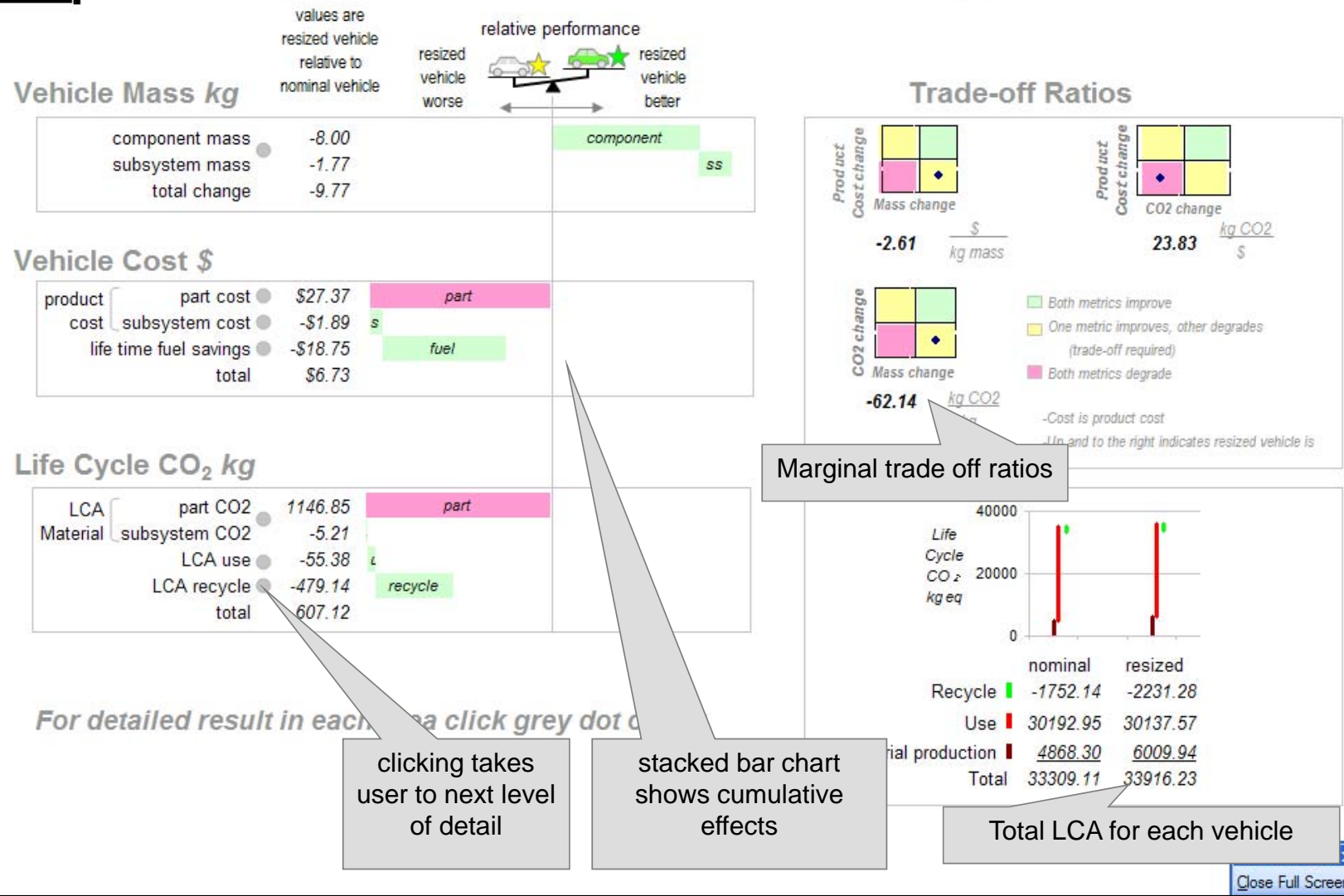
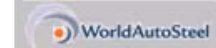
Full Screen  
Close Full Screen

# Design Advisor Solution Map



# Overview of Design Advisor – Summary output

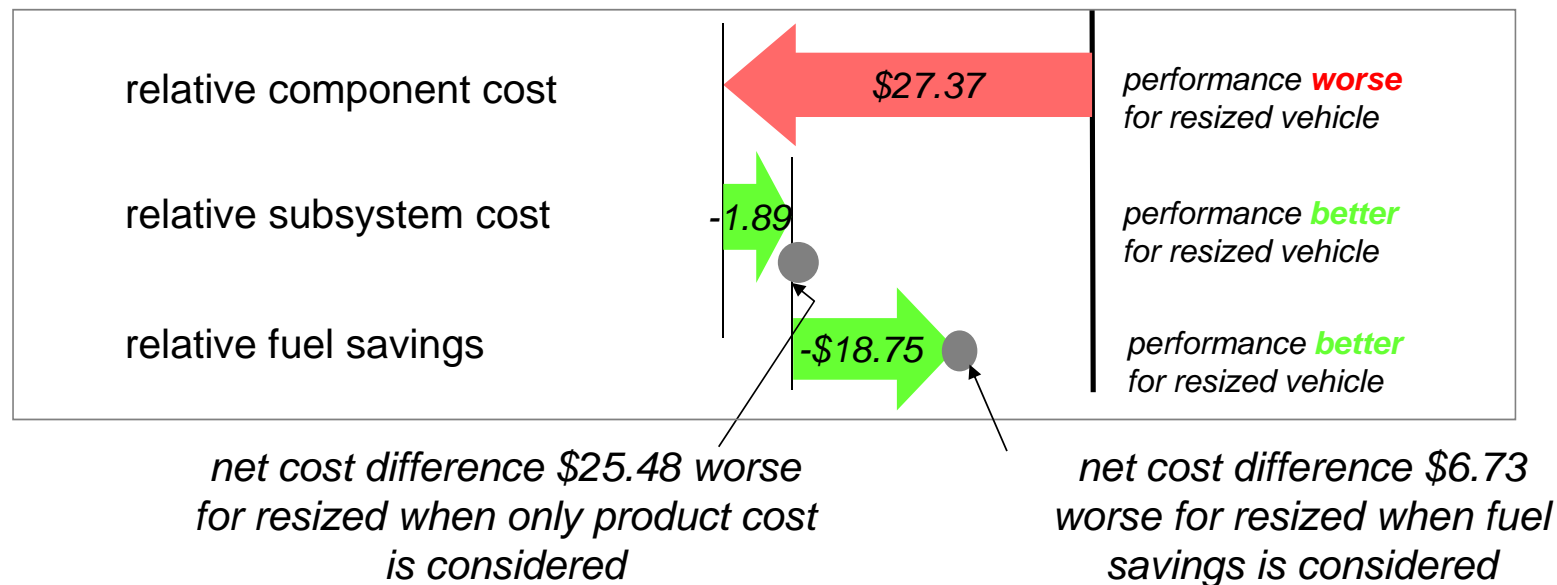
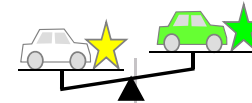
Comparison Summary - Difference between Nominal & Resized Vehicles



## Overview of Design Advisor – Summary output - Graphs

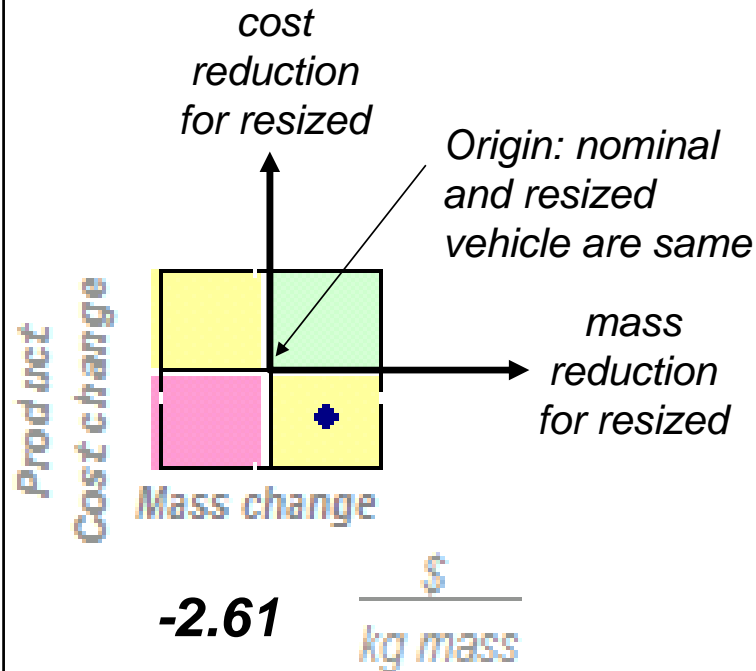
### Vehicle Cost \$

product	part cost	●	\$27.37	part
cost	subsystem cost	●	- \$1.89	ss
	life time fuel savings	●	\$18.75	fuel
	total		- \$6.73	



## Overview of Design Advisor–Summary output Trade-off ratios

### Trade-off ratio



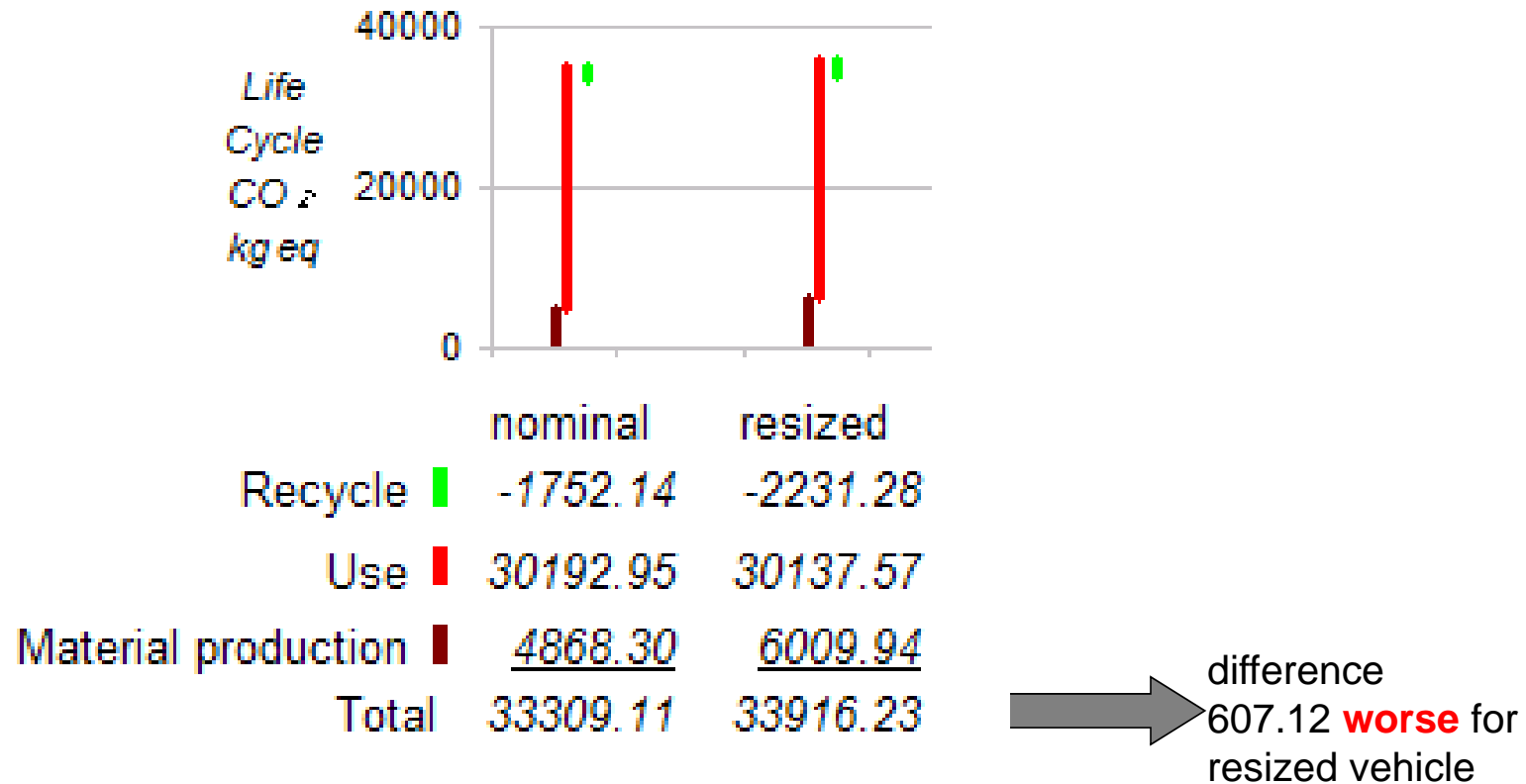
$$T.O.R. = \frac{\Delta \text{product cost}}{\Delta \text{mass}}$$

$+\$27.37 - \$1.89 = \$25.48$  increase in cost for a 9.77 kg mass reduction

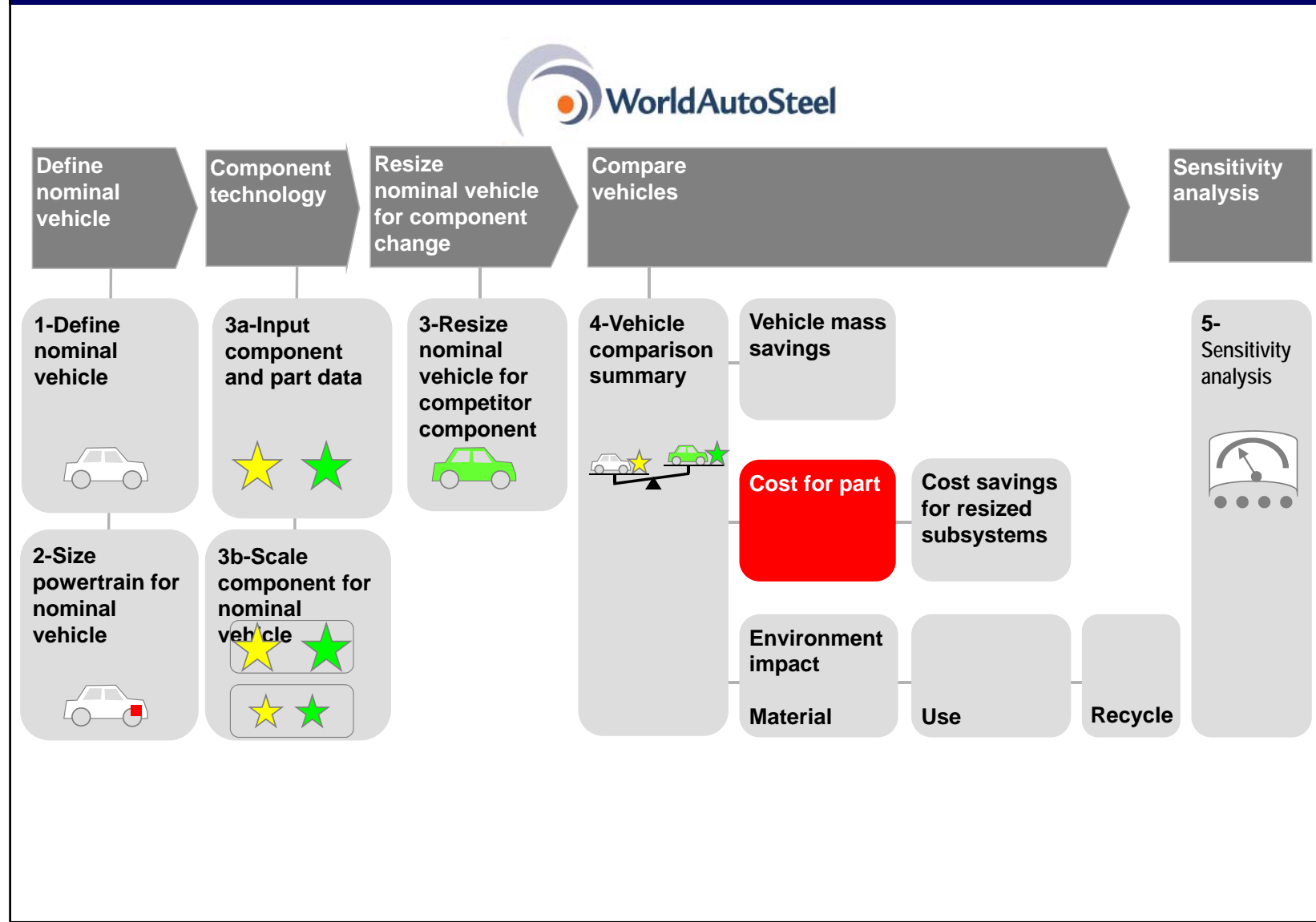
$$T. O. R. = \frac{\$25.48}{-9.77 \text{ kg}} = -2.61 \frac{\$ \text{ spent}}{\text{kg reduced}}$$

- quadrant where both metrics are better for resized vehicle relative to nominal
  - quadrant where both metrics are worse for resized vehicle
  - quadrant where one metric is better, one worse for resized vehicle
- Trade-off ratio significant**

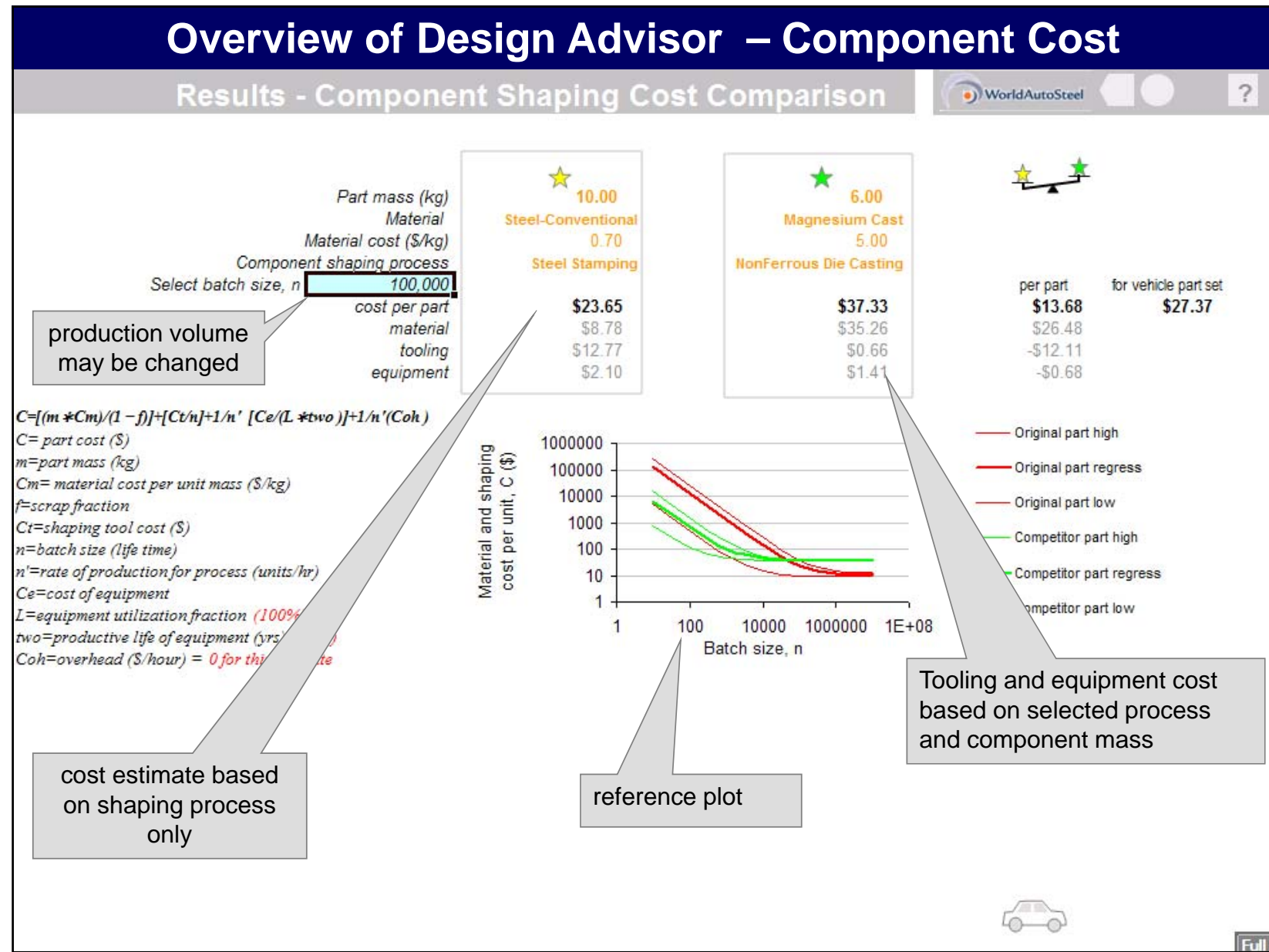
## Overview of Design Advisor–Summary output GHG LCA



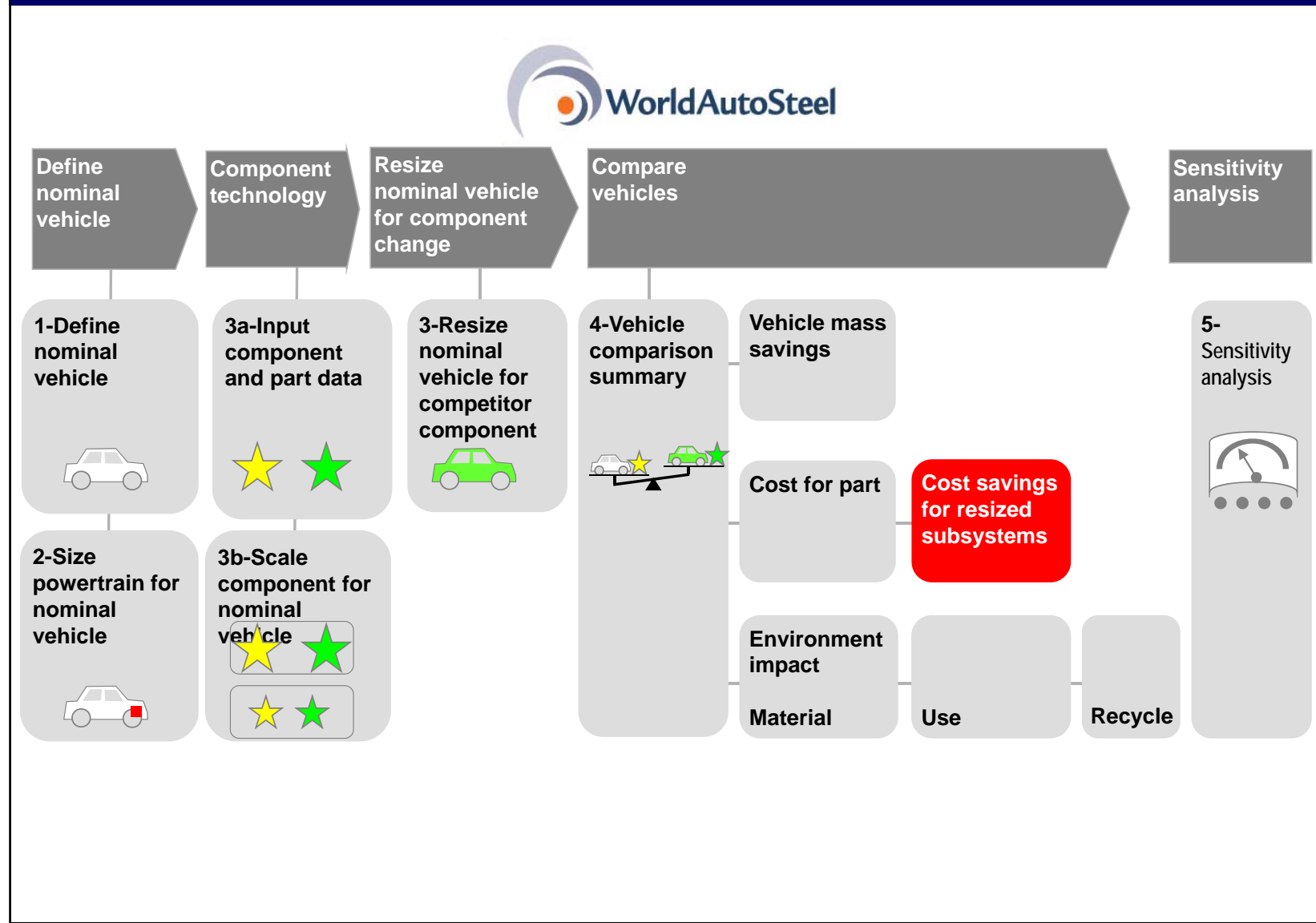
# Design Advisor Solution Map





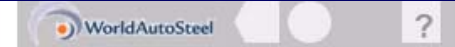


# Design Advisor Solution Map



# Overview of Design Advisor – Cost savings for resized subsystems

## Results - Cost savings for resized subsystems



User defined cost coefficients? ☐

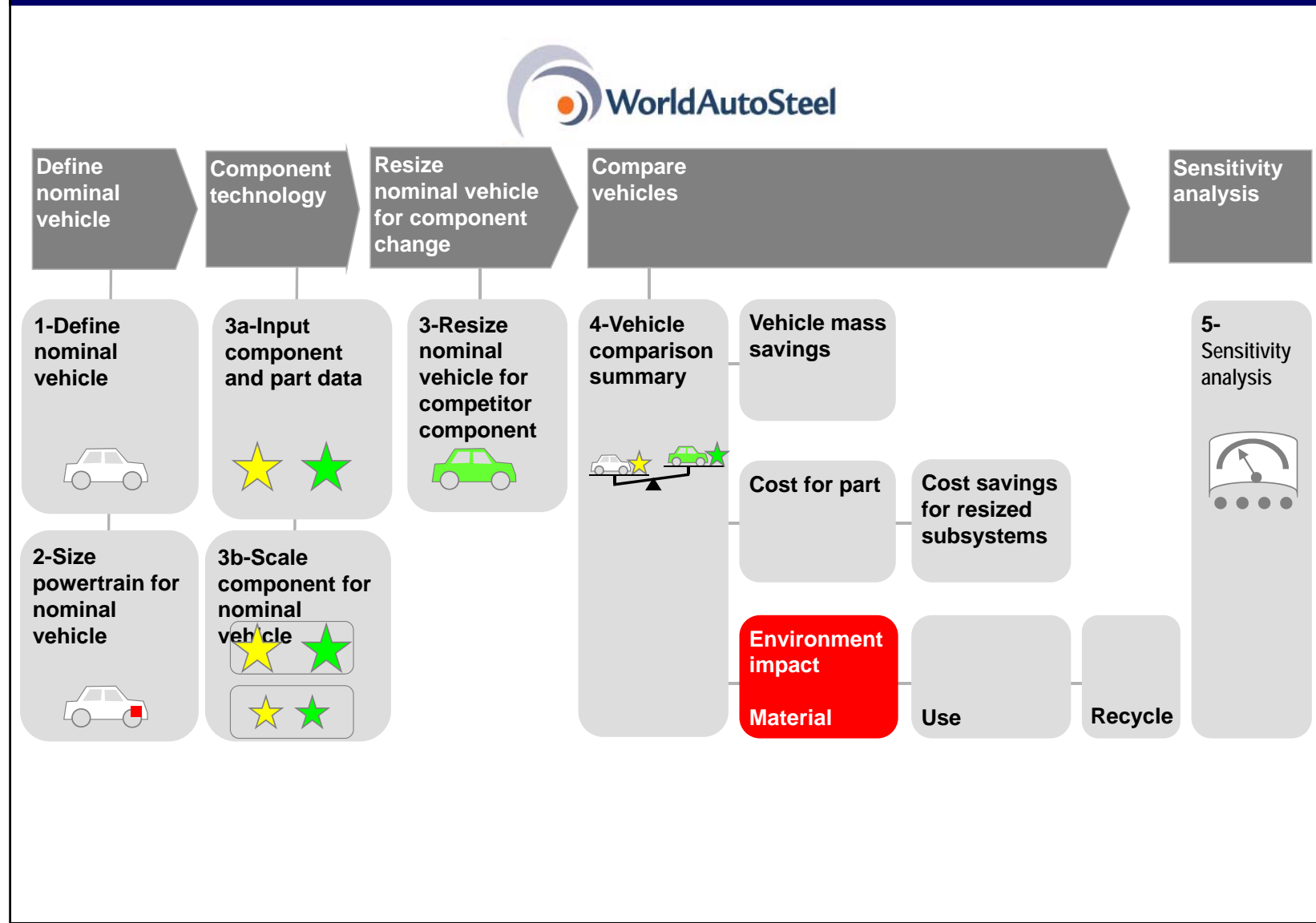
	\$/kg	\$/kg		kg	kg	\$		Referen
								Nomina
								Vehicle
								Material
								Cost
Subsystem	Subsystem Cost Coefficient	User defined cost coefficient	Consider Resizing Cost?	Nominal Vehicle Mass	Resized Vehicle Mass	Cost: Resized relative to nominal (\$)		
Body Non-structure	2.965			292.89	292.89	0.000		868.
Body Structure	0.852		<input checked="" type="checkbox"/>	325.91	325.15	-0.655		277.
Front Suspension	1.268		<input checked="" type="checkbox"/>	70.35	70.15	-0.251		89.
Rear Suspension	1.161		<input checked="" type="checkbox"/>	63.17	62.97	-0.230		73.
Braking	0.666		<input checked="" type="checkbox"/>	45.94	45.65	-0.195		30.
Powertrain	1.586		<input checked="" type="checkbox"/>	265.61	265.61	0.000		421.
Fuel & Exhaust	0.905		<input checked="" type="checkbox"/>	57.43	57.35	-0.073		51.
Steering	0.998		<input checked="" type="checkbox"/>	20.10	20.04	-0.056		20.
Tires & Wheels	2.449		<input checked="" type="checkbox"/>	93.32	93.15	-0.427		228.
Electrical	5.143			66.04	66.04	0.000		339.
Cooling	3.032		<input checked="" type="checkbox"/>	38.77	38.77	0.000		117.
Bumpers	.465		<input checked="" type="checkbox"/>	31.59	31.59	0.000		77.
Closures	.036			64.61	64.61	0.000		131.
Battery (electric car)	.250			0.00	0.00	0.000		0.
<b>Totals</b>				<b>1435.75</b>	<b>1433.98</b>	<b>-1.888</b>		<b>2727.</b>

Subsystem cost change per kg based on material cost

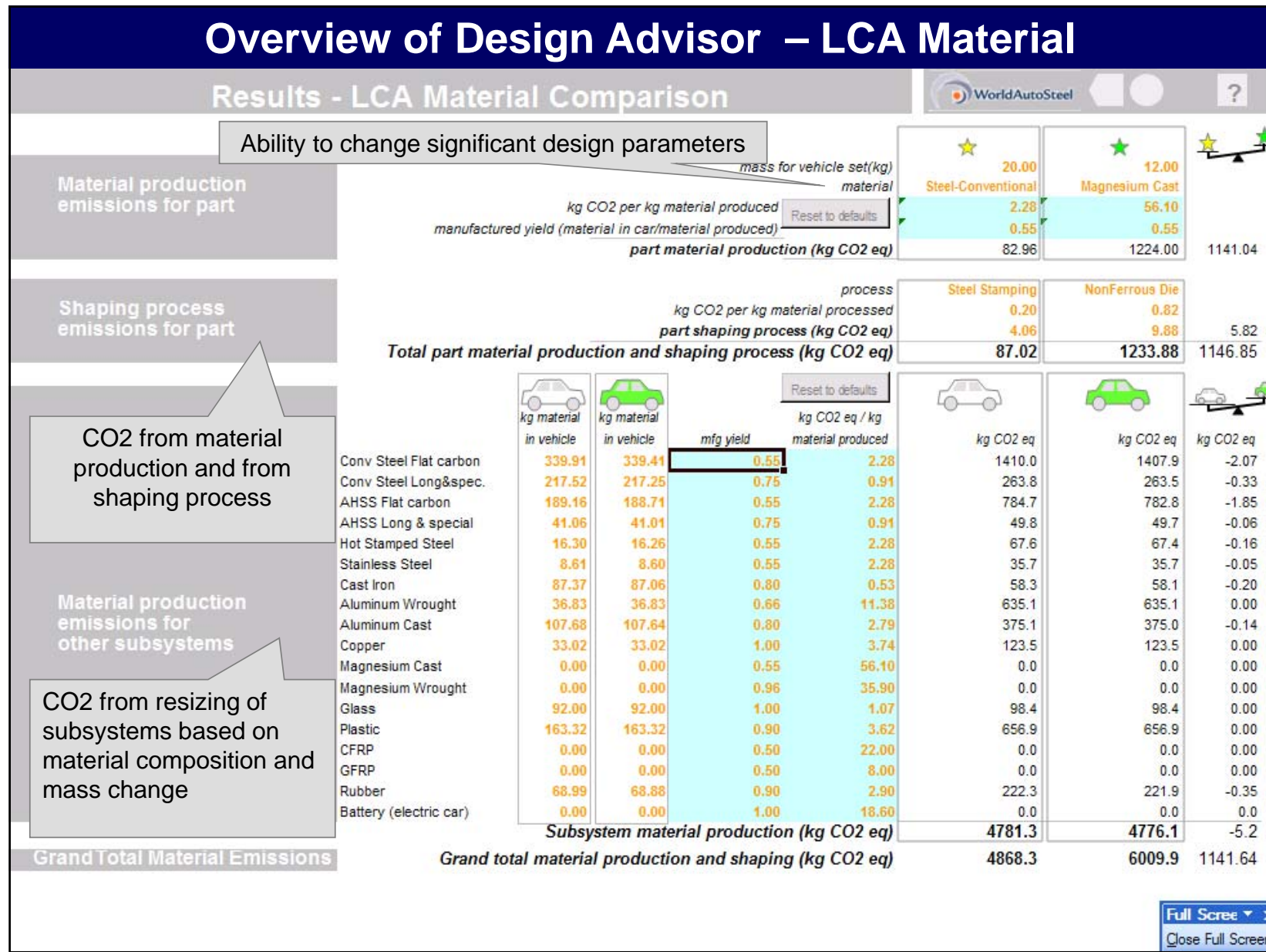
ability to include cost change or not include

Full Screen   
 Close Full Screen

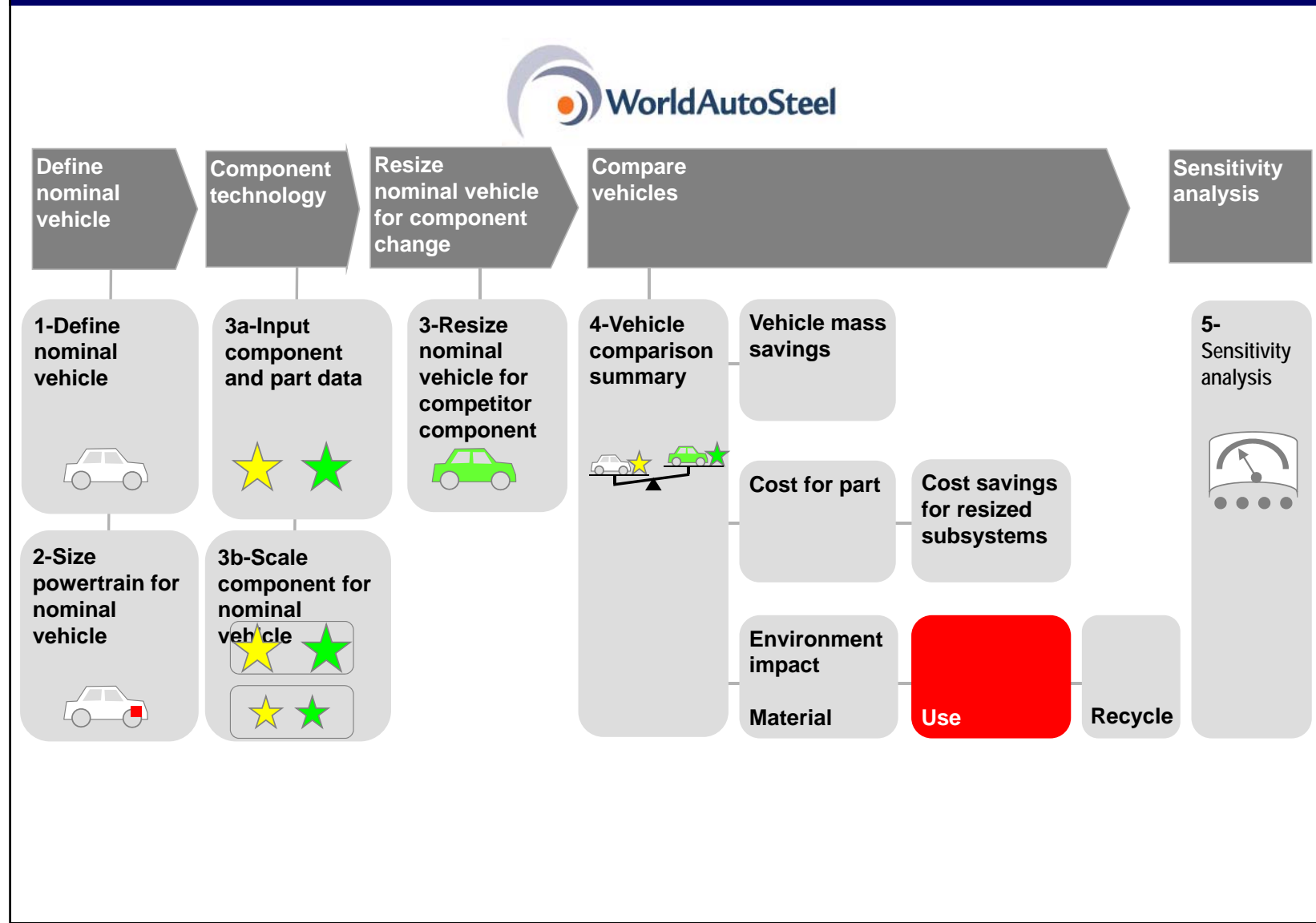
# Design Advisor Solution Map



# Overview of Design Advisor – LCA Material



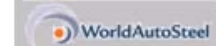
# Design Advisor Solution Map





# Overview of Design Advisor – LCA Use Phase

## Results - LCA Use Comparison



ability to resize  
powertrain for  
constant  
performance

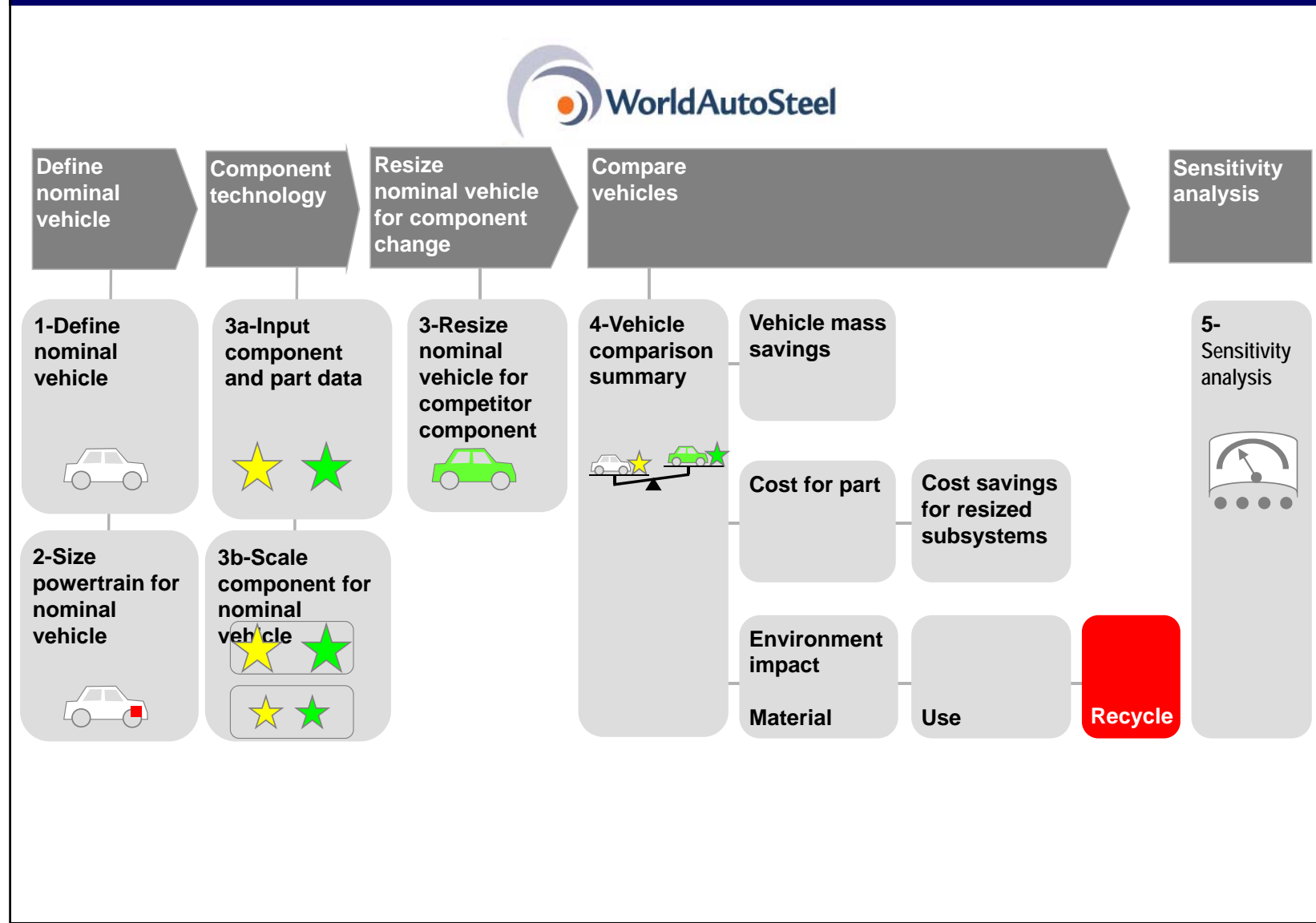
Selected fuel **Gasoline**  
 Selected powertrain technology **Internal Combustion-gasoline**  
 Selected driving schedule **HYZEM**  
 Selected fuel consumption **6.80 l/100km eq** **216.75 MJ/100km**  
 Selected life time range **155000 km**  
 Liquid fuel reduction value **0.1277 l/100km eq/100kg** **4.0693 MJ/100km/100kg**  
 Electricity consumption reduction value **0.0000 l/100km eq/100kg** **0.0000 MJ/100km/100kg**  
 Vehicle mass difference **-9.7696 kg**  
 Resize powertrain for equal performance? ☐ **FALSE**

Fuel consumption Reduction  
Value based on fka models

Fuel Consumption		Electricity		Liquid fuel		Electricity		Liquid fuel		Electricity	
Fuel Consumption	6.800 l/100km eq	0.000 kWh/100km		6.788 l/100km eq	0.000 kWh/100km			6.788 l/100km eq	0.000 kWh/100km		
	216.750 MJ/100km	0.000 MJ/100km		216.352 MJ/100km	0.000 MJ/100km			216.352 MJ/100km	0.000 MJ/100km		
Life time fuel use by source	10540 liter	0 kWh		10521 liter	0 kWh			10521 liter	0 kWh	-19.33	0
	335963 MJ	0 MJ/90%charge eff		335346 MJ	0 MJ/90%charge eff			335346 MJ	0 MJ/90%charge eff		
Total vehicle fuel demand-all sources	335,963 MJ			335,346 MJ				335,346 MJ		-616.21	
Fuel Consumption		Electricity		Liquid fuel		Electricity		Liquid fuel		Electricity	
Unit fuel cost	0.97 \$/l	0.97 \$/kwhr		0.97 \$/l	0.97 \$/kwhr			0.97 \$/l	0.97 \$/kwhr		
Life time fuel cost	\$10,224 \$	\$0 \$		\$10,205 \$	\$0 \$			\$10,205 \$	\$0 \$		
Total Life time cost	\$10,224 \$			\$10,205 \$				\$10,205 \$		-18.75	
Discount rate %/yr	5.0%										
Present value fuel cost (10yr)	\$7,895 \$			\$7,880 \$				\$7,880 \$		-14.48	
Tank to Wheel CO2 eq		Electricity		Liquid fuel		Electricity		Liquid fuel		Electricity	
Tank to wheels CO2 per unit fuel	0.072 kg CO2eq/MJ			0.072 kg CO2eq/MJ				0.072 kg CO2eq/MJ			
Life time CO2 from liquid fuel use	24156 kg CO2eq			24111 kg CO2eq				24111 kg CO2eq		-44.31	0
Well to Tank CO2 eq		Electricity		Liquid fuel		Electricity		Liquid fuel		Electricity	
Fuel production energy per unit output	0.210 MJ/MJ	0.210 MJ/MJ		0.210 MJ/MJ	0.210 MJ/MJ			0.210 MJ/MJ	0.210 MJ/MJ		
CO2 per unit energy production	0.018 kg CO2eq/MJ	0.018 kg CO2eq/MJ		0.018 kg CO2eq/MJ	0.018 kg CO2eq/MJ			0.018 kg CO2eq/MJ	0.018 kg CO2eq/MJ		
Fuel production energy	70552 MJ	0 MJ		70423 MJ	0 MJ			70423 MJ	0 MJ		
CO2 from fuel production by type	6037 kg CO2eq	0 kg CO2eq		6026 kg CO2eq	0 kg CO2eq			6026 kg CO2eq	0 kg CO2eq		
Life time CO2 from fuel production	6037 kg CO2eq			6026 kg CO2eq				6026 kg CO2eq		-11.07	
Well to Wheel Grand total		Electricity		Liquid fuel		Electricity		Liquid fuel		Electricity	
	30,193 kg CO2eq			30,138 kg CO2eq				30,138 kg CO2eq		-55.38	
	406,515 MJ			405,769 MJ				405,769 MJ			

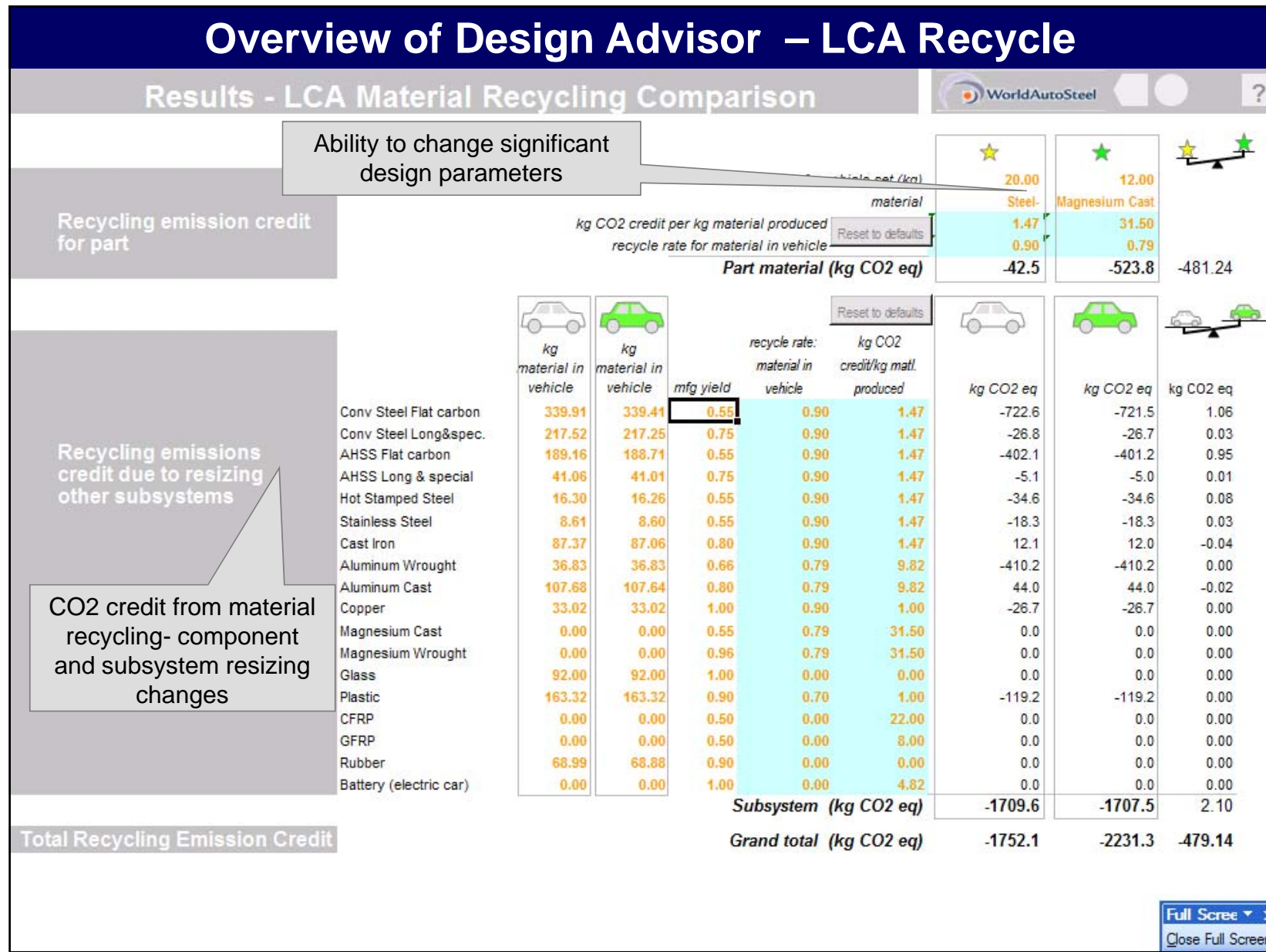
Full Screen >  
Close Full Screen

# Design Advisor Solution Map

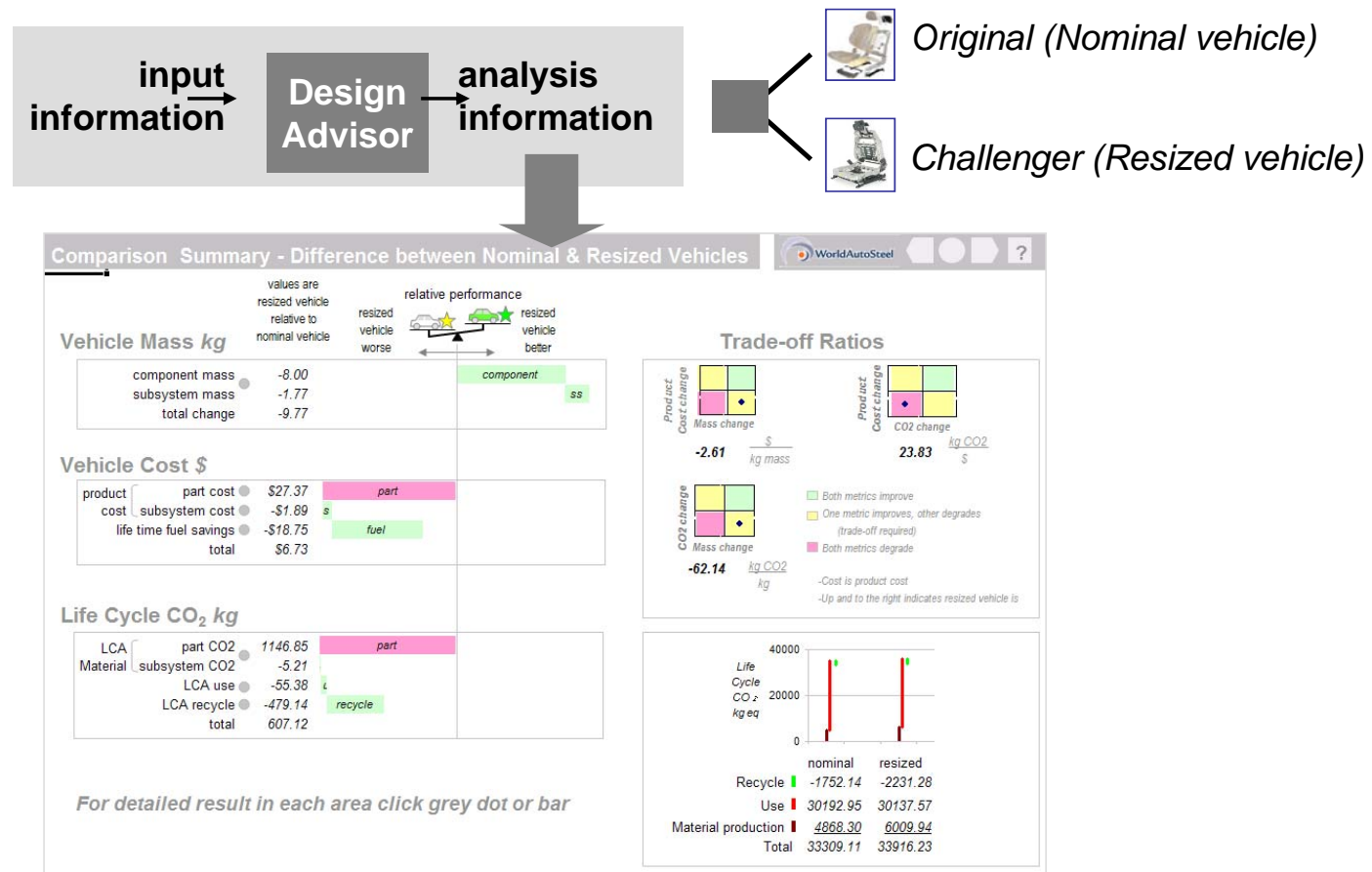


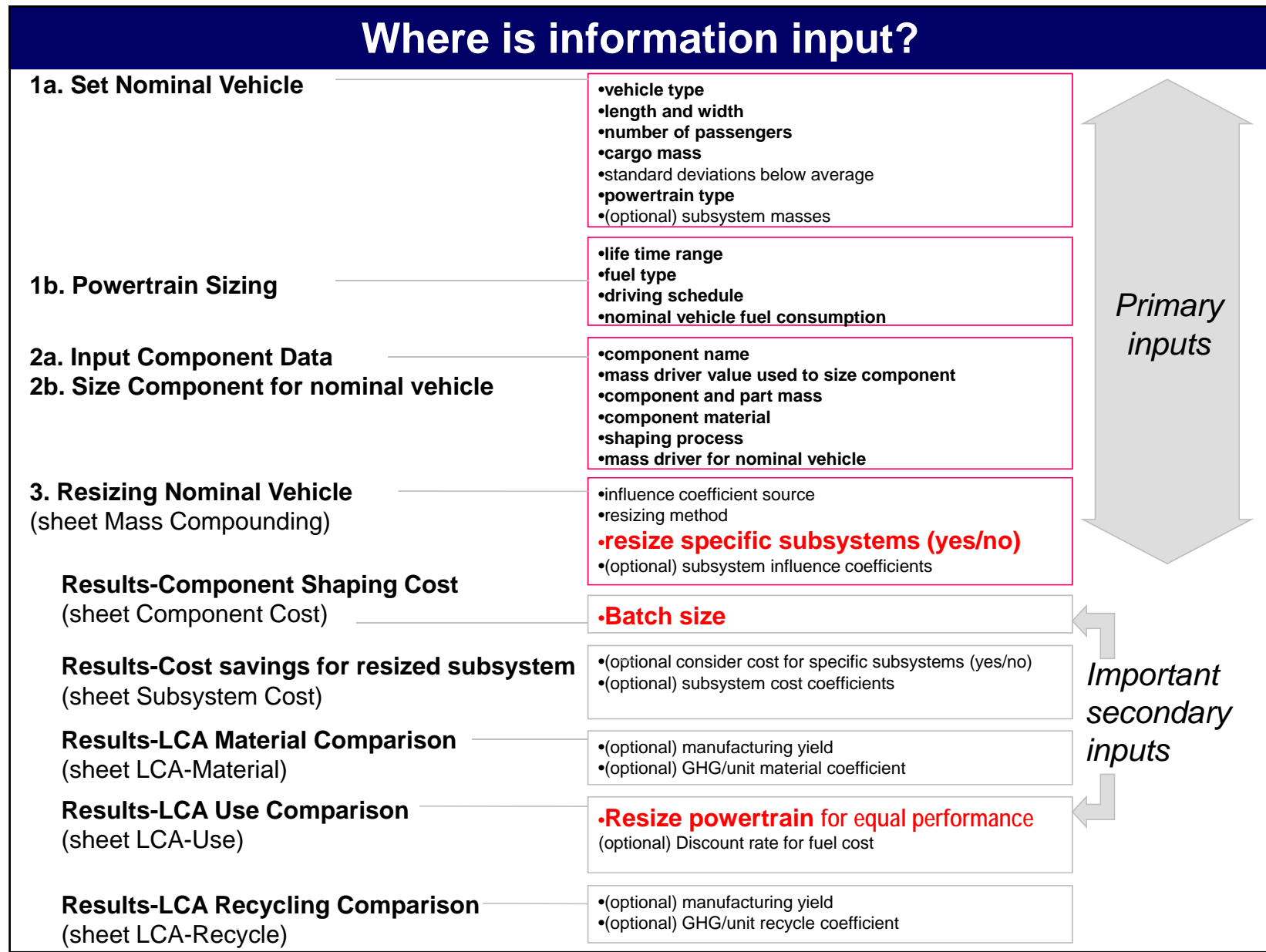


# Overview of Design Advisor – LCA Recycle



# Decision?





- Keep Excel open
- We will continue to use this same example

