



Analysis Report BAV 10-683-001_2B

**Light-Duty Vehicle Technology Cost Analysis
European Vehicle Market
Result Summary and Labor Rate Sensitivity Study**

REVISED FINAL REPORT

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Updates to “Light-Duty Vehicle Technology Cost Analysis, European Vehicle Market, Result Summary and Labor Rate Sensitivity Study”

The overall goal of this study was to provide accurate technology assessments through highly detailed and transparent cost analysis methodologies that compare and contrast differences and similarities between various technology configurations. Based on that goal, FEV is hereby issuing an update to the previously released report dated 4/10/13.

Within the Phase 1 configurations evaluated, minor revisions were made to the following two case studies:

1. 6-Speed Automatic Transmission (AT) to 6-Speed Dual Clutch Transmission (DCT)
2. 6-Speed Automatic Transmission to 8-Speed Automatic Transmission

The revisions to the two transmission case studies include updates to selected electronic components and component drivers which were overlooked in the original analyses. The inclusion of the missed hardware, from the original analyses, resulted in an ***increase*** in the Net Incremental Direct Manufacturing Costs (NIDMC) of approximately €38 for the 6-Speed DCT compared to the 6-Speed AT, and €10 for the 8-Speed AT compared to the 6-Speed AT.

The Phase 1 report “Light-Duty Vehicle Technology Cost Analysis – European Vehicle Market (Phase 1)” has been updated to reflect these changes. The update to the Phase 1 report comprised of refinements in cost analysis results obtained, as well as detailing the electronic control system component differentials between the compared transmissions.

These same changes have been added to Phase 1 results within this summary report for both the Western European and Eastern European analyses.

Updates to Tables in the Report Body

- Table A-1: Average Percent Reduction in Net Incremental Technology Costs with Average Labor Rate reduced by 77%, Phase 1 and Phase 2 Technology Configurations
- Table C 3: 6-Speed Automatic Transmission, 8-Speed Automatic Transmission, and 6-Speed Wet Dual Clutch Transmission Case Study Results

- Table D 3: 6-Speed Automatic Transmission, 8-Speed Automatic Transmission, and 6-Speed Wet Dual Clutch Transmission Case Study Results (Eastern Europe Labor Rate Substitution)
- Table D 17: Average Percent Reduction in Net Incremental Technology Costs with Average Labor Rate reduced by 77%, Phase 1 Technology Configurations

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A. Executive Summary

The International Council on Clean Transportation (ICCT) contracted with FEV, Inc. to define the net incremental costs for a set of advanced light-duty vehicle technologies for the European vehicle market. The technologies selected are on the leading edge for reducing fuel consumption and emissions of greenhouse gases in the future, primarily in the form of tailpipe carbon dioxide (CO₂). The work performed was compiled through a two-phase analysis: Phase 1 addressed the transfer and conversion of information and results from existing North American advance vehicle powertrain cost analysis studies into comparable European cost studies; Phase 2 carried on the Phase 1 project work with additional advance technology studies more common to the European market.

The following report summarizes the results from both the Phase 1 and Phase 2 studies. The full report for both studies, “Light-Duty Vehicle Technology Cost Analysis – European Vehicle Market (Phase 1)” and “Light-Duty Vehicle Technology Cost Analysis – European Vehicle Market, Additional Case Studies (Phase 2)” can be found at <http://www.theicct.org/light-duty-vehicle-technology-cost-analysis-european-vehicle-market>

Examples of the light-duty technologies evaluated in the Phase 1 and Phase 2 work are listed below.

Phase 1:

- Gasoline Direct Injection, Turbocharge, Downsized Engines
- 6 and 8-Speed Automatic Transmissions
- 6 and 8-Speed Wet Dual Clutch Transmissions
- Power-Split Hybrid Electric Vehicles
- P2 Hybrid Electric Vehicles

Phase 2:

- High-Pressure Diesel Fuel Injection Subsystem
- Variable Valve Timing and Lift Valvetrain Subsystem
- Diesel and Gasoline EGR Subsystems
- 6-Speed Dry Dual Clutch Transmission
- Belt-driven Starter Generator Stop-Start System

This report also includes a high level, labor cost sensitivity analysis for all technologies evaluated in the Phase 1 and Phase 2 study. The sensitivity analysis reduces the labor cost factor by approximately 77%; the difference between the average direct labor rate in Germany (€33.28/hour for suppliers and €44.16/hour for OEMs) versus an average of Eastern European Country labor rates (€7.75/hour for suppliers and €10.29/hour for OEMs). Replacing the Germany labor rates in the cost analyses with the average Eastern European rates reduces the advance technology costs between 2.3 to 21.3% as shown in Table A-1 below. A negative percentage in the table indicates the baseline technology is more expensive to manufacture. In these few cases, a reduction in labor rates reduces the savings as the baseline technology becomes less expensive to manufacture relative to the advance technology configuration.

Table A-1: Average Percent Reduction in Net Incremental Technology Costs with Average Labor Rate reduced by 77%, Phase 1 and Phase 2 Technology Configurations

Case Study ID	Baseline Technology Configuration	New Technology Configuration	Average Percent NITC Reduction Assuming Average Eastern European Labor Rate ¹
01**	Naturally Aspirated (NA), Port Fuel Injected (PFI), Gasoline Internal Combustion Engine (ICE)	Downsized (DS), Turbocharged (Turbo), Direct Injection (DI) Gasoline Internal Combustion Engine (ICE)	21.3%
02**	Dual Overhead Cam (DOHC), NA, PFI, Dual-Variable Valve Timing (D-VVT), Gasoline ICE	Single Overhead Cam (SOHC), NA, PFI, Multi-Air Variable Valve Timing and Lift (VVTL), Gasoline ICE	18.8%
08**	5-Speed Automatic Transmission	6-Speed Automatic Transmission	-19.5%
10**	6-Speed Automatic Transmission	8-Speed Automatic Transmission	17.7%
09**	6-Speed Automatic Transmission	6-Speed Dual Clutch Transmission	-27.3%
04**	Conventional Powertrain Vehicle	Conventional Powertrain Vehicle Upgraded with a Belt Alternator Starter (BAS) Start-Stop System	19.1%
05**	Conventional Powertrain Vehicle	Power-Split Hybrid Electric Vehicle	15.2%
07**	Conventional Powertrain Vehicle	P2 Hybrid Electric Vehicle	15.5%
06**	Mechanical Air Conditioning Compressor System	Electrical Air Conditioning Compressor System	2.3%
20**	Conventional Diesel Engine	Downsized Conventional Diesel Engine (e.g. I4-I3, I6-I4, V8-I6)	-19.2%
21**	Conventional Diesel Engine with 1800 Bar Fuel Injection Subsystem	Conventional Diesel Engine Upgraded with 2500 Bar Fuel Injection Subsystem	5.3%
22**	Diesel Engine with Conventional Valvetrain Subsystem	Diesel Engine Upgraded with Discrete Variable Valve Timing and Lift (DVVT) Valvetrain subsystem	19.1%
23**	Conventional Diesel Engine with a Cooled High Pressure Exhaust Gas Recirculation (EGR) Subsystem	Conventional Diesel Engine Upgraded with a High Pressure, Low Pressure Cooled High EGR Subsystem	18.9%
31**	Conventional Gasoline Engine with a Uncooled Low Pressure EGR Subsystem	Conventional Gasoline Engine Upgraded with a Cooled Low Pressure EGR Subsystem	19.1%
32**	Conventional Gasoline Engine with no EGR Subsystem	Conventional Gasoline Engine Upgraded with a Cooled Low Pressure EGR Subsystem	19.1%
26**	6-Speed Manual Transmission	6-Speed Dry Dual Clutch Transmission (DCT)	19.1%
30**	Conventional Powertrain Vehicle (Manual Transmission)	Conventional Powertrain Vehicle ((Manual Transmission) Upgraded with a Belt-Driven Starter Generator (BSG) Start-Stop System	19.2%

Notes: ¹ Negative percentage indicates reduced savings as the base technology is less expensive to manufacture in the low cost country (i.e., Eastern Europe)

B. Introduction

This report summarizes the results from two previously completed light-duty vehicle technology cost studies FEV conducted for ICCT. Both studies investigated the incremental costs to update conventional light-duty vehicle technology configurations, with various advanced technology configurations, aimed towards improving fuel economy and reducing greenhouse gas emissions. The first study, also referred to as the Phase 1 analysis, primarily involved the conversion and transformation of existing cost models completed for the United States Environmental Protection Agency into models representative of the technology and vehicle segments in the European market. The Phase 2 study developed new cost models for additional technologies, more applicable to the European market, selected by the ICCT team.

In addition to summarizing the results from the Phase 1 and Phase 2 studies, a larger sensitivity study is included in this report assessing the impact of labor rates on all the incremental technology costs evaluated in the Phase 1 and Phase 2 reports. Reducing the labor rate for all the studies by approximately 77%, the difference between the average German labor rate used in the analyses and a calculated average Eastern Europe rate, new Net Incremental Direct Manufacturing Costs (NIDMCs) and Net Incremental Technology Costs (NITCs) were calculated for each case study.

B.1 Phase 1 and Phase 2 Study Overview

The initial study, *“Light-Duty Vehicle Technology Cost Analysis – European Vehicle Market (Phase 1),”* addressed the transfer and conversion of information and results from existing advance vehicle powertrain cost analysis studies performed by FEV, based on previously completed detail teardown and cost analysis work conducted for the U.S. Environmental Protection Agency (EPA) by FEV and its subcontractors in a North American context. Accounting for key differences in manufacturing costs (e.g. material, labor, and manufacturing overhead) and vehicle segment performance attributes (e.g. engine horsepower, torque, displacement and configuration) EPA cost models were converted into European models. The updated European cost models calculate the Net Incremental Direct Manufacturing Cost (NIDMC) based on Western European cost factors (e.g. material, labor, manufacturing overhead).

The NIDMC is the incremental difference in cost of components and assembly, to the OEM, between the new technology configuration and a baseline technology configuration (i.e. $NIDMC = \text{Direct Manufacturing Cost of New Technology Configuration} - \text{Direct Manufacturing Cost of the Baseline Technology Configuration}$). For each incremental cost comparison, the new technology configuration, and baseline technology

configuration (also referred to as the conventional technology configuration or current industry standard) share similar primary function and performance attributes.

The cost factors included and excluded in the direct manufacturing costs calculations are shown below in **Figure B-1**.

	Direct Manufacturing Costs (DMCs)							
	Total Manufacturing Costs			Mark-Up				Packaging
	Material	Labor	Manufacturing Overhead	End-Item Scrap	SG&A	Profit	ED&T	Packaging
Supplier Fabrication and Assembly	Included	Included	Included	Included	Included	Included	Included	Included
OEM Fabrication and Assembly	Included	Included	Included	Excluded	Excluded	Excluded	Excluded	Included

Figure B-1: Cost Factors Included in Direct Manufacturing Costs

In order to calculate the cost impact of a new technology configuration on multiple vehicle segments a cost scaling process was employed. Physical attributes (e.g. quantity, mass, geometric size) and performance attributes (e.g. torque, power) of the technology under evaluation, are analyzed between the lead case study vehicle segment and the remaining vehicle segment. Based on identified attributes differences, cost scaling factors are established to translate the Net Incremental Direct Manufacturing Costs (NIDMCs) from the lead case study vehicle segment to alternative vehicle segments.

Two factors (ICM and Leaning), both production-year dependent, are applied to the NIDMCs to arrive at Net Incremental Technology Costs (NITC). The NITC is the estimated incremental cost an OEM would be expected to sell the new technology configuration at, relative to the baseline technology configuration, in a given production year.

The indirect cost multiplier (ICM) factor addresses the OEM indirect costs associated with manufacturing new components and assemblies. The ICM includes indirect costs associated with OEM engineering, design and testing (ED&T), corporate operations, dealership support, sales and marketing material, legal, and OEM owned tooling. The ICM contribution is calculated by applying an ICM factor to the NIDMC.

The ICM methodology and values were developed by the United States EPA as an alternative method for accounting for indirect costs, to the existing retail price equivalent (RPE) methodology. The EPA felt that some of the contributors to RPE, like fixed depreciation costs, health care costs of retired workers, and pension costs, may not be affected by the addition of all new vehicle technologies as a result of imposed regulation. Hence, the EPA developed this modified multiplier referred to as the ICM. In addition,

the EPA developed a range of ICMs accounting for differences in technology complexity levels and technology maturity. More details on the development of ICMs can be found in the EPA published report “Automobile Industry Retail Price Equivalent and Indirect Cost Multiplier” EPA-420-R-09-003, February 2009.

In addition to the application of indirect cost multipliers, to net incremental direct manufacturing costs, a second factor referred to as a “learning curve factor,” or “experience curve factor,” are also applied. The learning curve factors address the anticipated reduction in direct manufacturing costs as a result of “getting smarter” on the product design and /or manufacturing of the product as a function of the number of units produced. Similar to the acquisition of the ICM values, learning factors developed by EPA for previous reports were also utilized in the ICCT analyses.

The “*Light-Duty Vehicle Technology Cost Analysis - European Market, Additional Case Studies (Phase 2)*” then continued the analysis work begun in Phase 1, however with new powertrain technology evaluations **not** studied previously as part of either ICCT or EPA work. Phase 2 was an all-new study conducted using EPA methodology and European cost values, requiring new teardowns, hardware assessments, and cost models. The same boundary conditions, costing assumptions and general vehicle segment attributes were maintained between the Phase 1 and Phase 2 studies providing a level playing field for comparison.

B.2 Labor Cost Sensitivity Study

B.2.1 Background

As part of the cost analysis work, a set of study boundary conditions is established to define a common framework for all costing models. The common framework permits reliable comparison of costs between (1) new and baseline technology configurations evaluated in the same analysis, and (2) between competing new technology configurations from two different analyses. In addition, having a good understanding of the analysis boundary conditions (i.e., what assumptions are made in the analysis, the methodology utilized, what parameters are included in the final numbers, etc.), a fair and meaningful comparison can be made between results developed from alternative costing methodologies and/or sources.

Parameters which make-up the boundary conditions include production volumes, production timeframe, production location, timeframe for material costs, labor costs, and manufacturing overhead costs (e.g. utility costs, facility costs, financing expense). For the ICCT European cost analysis, FEV chose Germany as the production location for all components within all studies. Therefore all cost factors associated with manufacturing (e.g. material cost, labor costs, manufacturing overhead, etc.) are generally based on

German market conditions. This costing approach may be viewed as conservative in nature as automotive components are manufactured worldwide; in both heavy industrialized nations as well as low cost countries.

Figure B-2 provides a list of major automotive suppliers and some of their Eastern European manufacturing locations.

Figure B-3 provides the hourly compensation costs (i.e., average labor rates) for selected countries in Euros. In comparison, the average automotive part manufacturing rate (i.e., component supplier rate) used in the ICCT analysis was €33.28/hour. For automotive vehicle manufacturing (i.e., OEM manufacturing) the rate used in the analysis was €44.16/hour.

To fully understand the level of conservatism in the calculated NITCs, one would need to evaluate the actual cost differential of producing components in higher technology based Western European industrialized nations (i.e., Germany, Great Britain, Italy, France) versus lower industrialized Eastern European nations (i.e., Ukraine, Romania, Czech Republic, Poland). In addition to material, labor and overhead cost structures being different, the actual manufacturing processes and equipment would also be considerably different; taking advantage of a low cost labor workforce versus high technology equipment and automation. New value stream maps for each component would need to be developed to assess which low cost countries would likely produce specific components. In addition special consideration to product fallout/scrap rates and other mark-up categories such as corporate overhead would need to be revisited in the cost models.

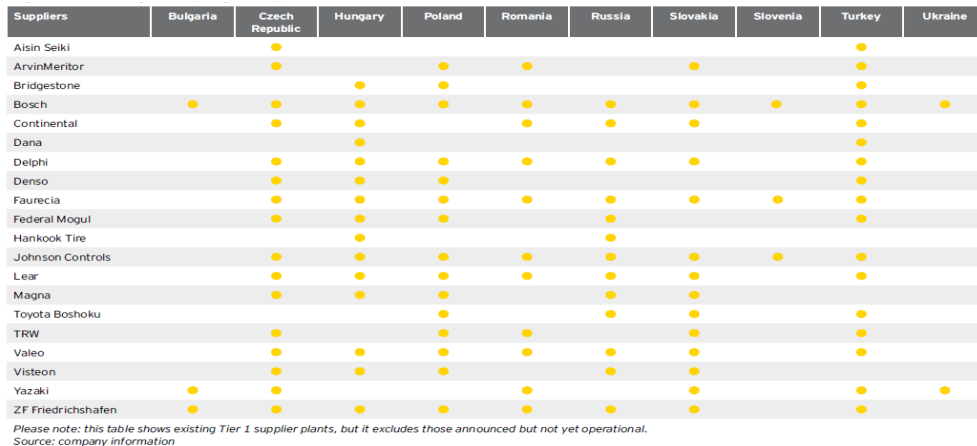


Figure B-2: Automotive Supplier Production Locations in Eastern Europe¹

¹ Ernst & Young, "The Central and Eastern European automotive market Industry overview", 2010

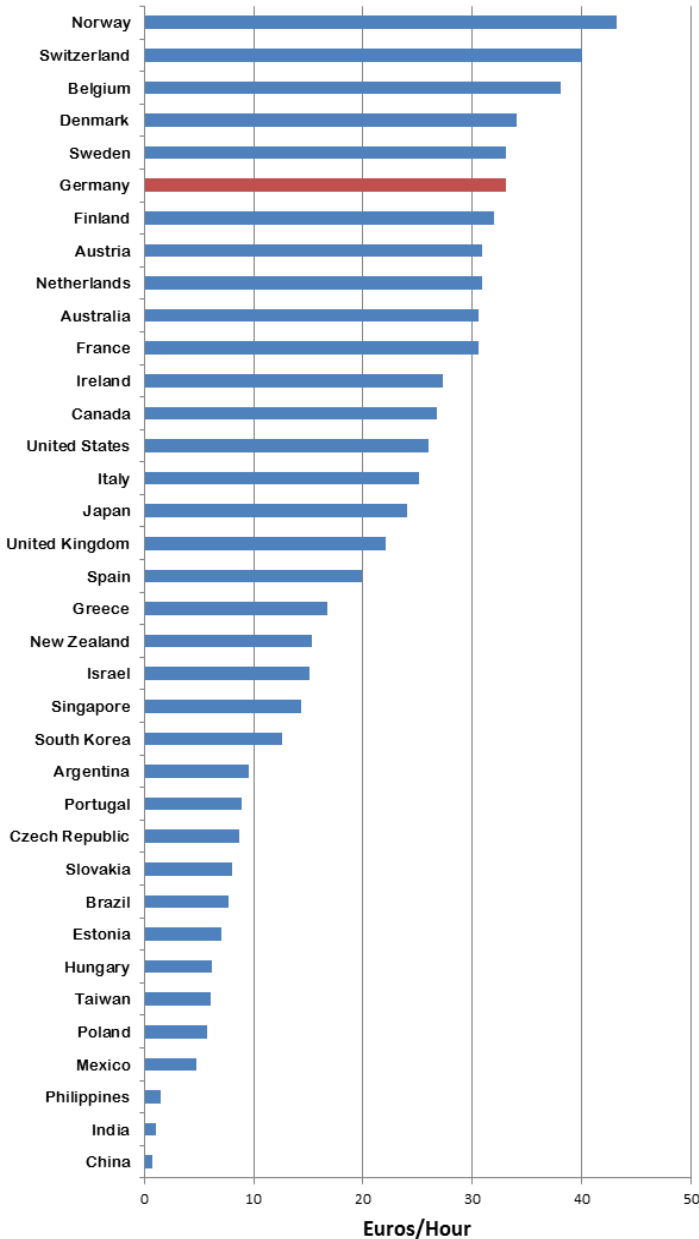


Figure B-3: Hourly Compensation/Labor Costs for Selected Manufacturing Countries (2010 Calendar Year)^{2,3}

² United States Bureau of Labor Statistics and Department of Labor, "Charting International Labor Comparisons 2012 Edition, September 2012.

³ Hourly rates were converted from U.S. dollars (as published in the original report) at an exchange rate of 1.326 US dollars to 1 Euro.

A detailed study comparing the technology cost differentials, as if they were manufactured solely in Western Europe versus Eastern Europe, was outside the scope of this analysis due to timing and funding constraints. As an alternative a labor sensitivity study was conducted in which the average labor cost contribution for each analysis was reduced by approximately 77 percent. The reduction represents the difference in labor costs between Germany and the average of six low cost Eastern Europe countries (**Figure B-4**). The six countries selected produce automotive components today.

Based on the 77% rate reduction, the average labor rates used in the Eastern European sensitivity analysis were €7.75/hour for supplier labor and €10.29/hour for OEM labor.

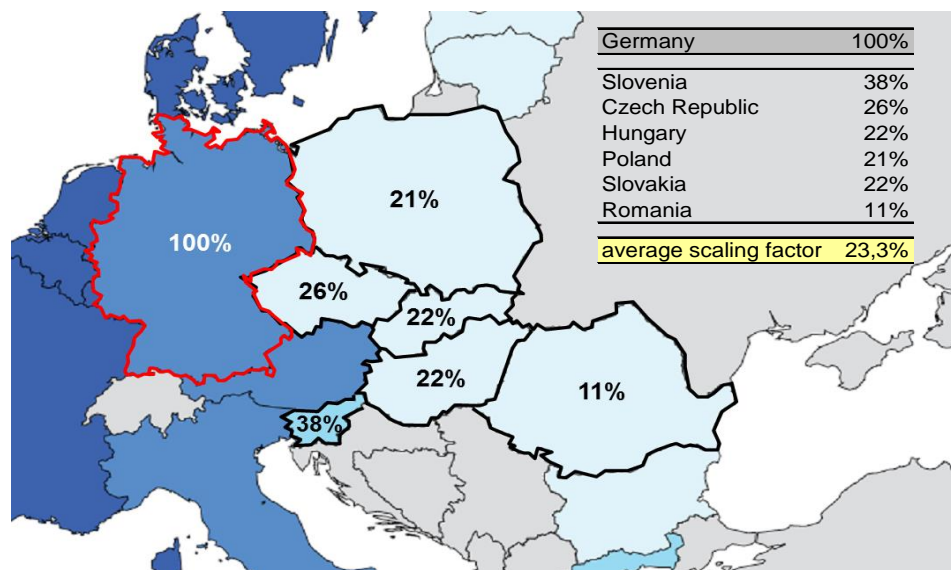


Figure B-4: Eastern Europe Labor Rate Averages Relative to Germany⁴

⁴D-Statistics Wissen.Nutzen, “Earnings and Labor Costs 2008”, May 13, 2009
<https://www.destatis.de/DE/Startseite.html>,

C. Phase 1 and Phase 2 Results

Section C.1 and C.2 below provide a summary of the calculated incremental costs for each of the technologies and vehicle segments evaluated in the Phase 1 and Phase 2 analyses. The number of vehicle segments evaluated varied for each technology configuration based on customer requirements. For each cost analysis, a case study ID exists corresponding to a technology type and vehicle class.⁵

The cost summary tables below present net incremental direct manufacturing costs (NIDMCs) and net incremental technology costs (NITCs) for production years 2012, 2016, 2020 and 2025.

C.1 Phase 1 Technologies Evaluated

A summary of the baseline and new technology configurations evaluated in the original Phase 1 analysis, and reference to the corresponding cost summary tables, is summarized below in **Table C-1**.

Table C-1: Advance Powertrain Technologies Evaluated in the Phase 1 Analysis

Case Study ID	Baseline Technology Configuration	New Technology Configuration	Cost Summary Table
01**	Naturally Aspirated (NA), Port Fuel Injected (PFI), Gasoline Internal Combustion Engine (ICE)	Downsized (DS), Turbocharged (Turbo), Direct Injection (DI) Gasoline Internal Combustion Engine (ICE)	C-2
02**	Dual Overhead Cam (DOHC), NA, PFI, Dual-Variable Valve Timing (D-VVT), Gasoline ICE	Single Overhead Cam (SOHC), NA, PFI, Multi-Air Variable Valve Timing and Lift (VVTL), Gasoline ICE	C-2
08**	5-Speed Automatic Transmission	6-Speed Automatic Transmission	C-3
10**	6-Speed Automatic Transmission	8-Speed Automatic Transmission	C-3
09**	6-Speed Automatic Transmission	6-Speed Dual Clutch Transmission	C-3
04**	Conventional Powertrain Vehicle	Conventional Powertrain Vehicle Upgraded with a Belt Alternator Starter (BAS) Start-Stop System	C-4
05**	Conventional Powertrain Vehicle	Power-Split Hybrid Electric Vehicle	C-5
07**	Conventional Powertrain Vehicle	P2 Hybrid Electric Vehicle	C-6
06**	Mechanical Air Conditioning Compressor System	Electical Air Conditioning Compressor System	C-7

⁵ Case Study ID Number: The first two digits identify the technology (e.g., 02** = engine downsizing analysis) and the second two digits identify the vehicle segment (e.g., **00 = subcompact passenger vehicle segment). The letter following the four digit number represents one possible powertrain option in that particular vehicle segment (i.e., 0200A = engine downsizing analysis, subcompact passenger vehicle segment, I3 engine configuration). In this particular example the letter "B" would signify an I4 engine configuration for the same analysis and vehicle segment.

Table C-2: Downsized, Turbocharged, Direct Injection Gasoline Engine & Multi-Air Variable Valve Timing and Lift Valvetrain Subsystem Case Study Results

Technology ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
							2012	2016	2020	2025
Engine										
Downsized, Turbocharged, Gasoline Direct Injection Internal Combustion Engines										
1	0100	1.4L, I4, 4V, DOHC, NA, PFI, dVVT, ICE	1.0L, I3, 4V, DOHC, Turbo, GDI, dVVT, ICE	Subcompact Passenger Vehicle	VW Polo	€ 230	€ 423	€ 379	€ 305	€ 276
2	0101	1.6L, I4, 4V, DOHC, NA, PFI, dVVT, ICE	1.2L, I4, 4V, DOHC, Turbo, GDI, dVVT, ICE	Compact or Small Passenger Vehicle	VW Golf	€ 360	€ 511	€ 466	€ 402	€ 372
3	0102	2.4L, I4, 4V, DOHC, NA, PFI, dVVT, ICE	1.6L, I4, 4V, DOHC, Turbo, GDI, dVVT, ICE	Midsized Passenger Vehicle	VW Passat	€ 367	€ 532	€ 484	€ 415	€ 383
4	0103	3.0L, V6, 4V, DOHC, NA, PFI, dVVT, ICE	2.0L, I4, 4V, DOHC, Turbo, GDI, dVVT, ICE	Midsized or Large Passenger Vehicle	VW Sharan	€ 80	€ 379	€ 328	€ 223	€ 189
5	0106	5.4L, V8, 3V, SOHC, NA, PFI, sVVT, ICE	3.5L V6, 4V, DOHC, Turbo, GDI, dVVT, ICE	Large SUV	VW Touareg	€ 648	€ 992	€ 900	€ 760	€ 698
Variable Valve Timing and Lift, Fiat MultiAir System										
6	0200	1.4L, I4, 4V, DOHC, NA, PFI, dVVT, ICE	1.4L, I4, 4V-MultiAir, SOHC, NA, PFI, ICE	Subcompact Passenger Vehicle	VW Polo	€ 107	€ 159	€ 145	€ 126	€ 117

Table C-3: 6-Speed Automatic Transmission, 8-Speed Automatic Transmission, and 6-Speed Wet Dual Clutch Transmission Case Study Results

Technology ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
							2012	2016	2020	2025
Transmissions	1	5-Speed AT	6-Speed AT	Midsized or Large Passenger Vehicle	VW Sharan	(€ 79)	(€ 60)	(€ 60)	(€ 63)	(€ 63)
	2	6-Speed AT	8-Speed AT	Large SUV	VW Touareg	€ 52	€ 73	€ 67	€ 58	€ 54
	3	6-Speed AT	6-Speed Wet DCT	Midsized or Large Passenger Vehicle	VW Sharan	(€ 83)	(€ 51)	(€ 51)	(€ 59)	(€ 59)

Table C-4: Belt Alternator Starter (BAS) Start-Stop System Case Study Results

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Start-Stop HEV	1	0402	Conventional Powertrain >I4 Gasoline ICE, 4V, DOHC, NA, PFI, VVT >4-Speed AT	Belt Alternator Starter (BAS) - HEV (Brake Regen & Launch Assist) >I4 Gasoline ICE, 4V, DOHC, NA, PFI, VVT >4-Speed AT >Electric Generator/Starter 14.5kW >Battery: 36V, 18.4Ah NiMH	Midsized Passenger Vehicle	VW Passat	€ 1,176	€ 2,323	€ 1,632	€ 1,378	€ 1,226

Table C-5: Power-Split Hybrid Electric Vehicle Case Study Results

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Power-Split HEV	1	0500	Subcompact car typically powered by an inline 4 cylinder engine, naturally aspirated, port fuel injection, 5-speed manual transmission (MT).	Power-split HEV System Power: 74.7kW ICE Power: 61.1kW (I4 -> I3) Traction Motor: 50kW Generator: 35.1kW Li-Ion Battery: 140V, 0.743kWh	Subcompact Passenger Vehicle	VW Polo	€ 1,809	€ 4,555	€ 3,506	€ 2,624	€ 2,158
	2	0501	Compact or small car typically powered by an inline 4 cylinder engine, naturally aspirated, port fuel injection, 6-speed manual transmission or 7-speed dual clutch transmission (DCT).	Power-split HEV System Power: 90kW ICE Power: 73.6kW (I4 - DS I4) Traction Motor: 60.2kW Generator: 42.3kW Li-Ion Battery: 162V, 0.857kWh	Compact or Small Passenger Vehicle	VW Golf	€ 2,012	€ 5,034	€ 3,883	€ 2,908	€ 2,397
	3	0502	A midsize passenger car typically powered by a 4 cylinder turbocharged, direct fuel injection, 6-speed MT and AT or 7-speed DCT, Start/Stop system.	Power-split HEV System Power: 117kW ICE Power: 95.6kW (I4 -> DS I4) Traction Motor: 78.3kW Generator: 55kW Li-Ion Battery: 188V, 0.994kWh	Midsize Passenger Vehicle	VW Passat	€ 2,230	€ 5,632	€ 4,331	€ 3,240	€ 2,663
	4	0503	A midsize or large passenger car typically powered by 4 and 6 cylinder turbocharged, direct fuel injection, 6-speed MT or ≥ 6 speed AT.	Power-split HEV System Power: 174.8kW ICE Power: 142.8kW (V6 -> I4) Traction Motor: 116.9kW Generator: 82.1kW Li-Ion Battery: 211V, 1.118kWh	Midsize or Large Passenger Vehicle	VW Sharan	€ 2,215	€ 5,802	€ 4,410	€ 3,282	€ 2,671
	5	0505	A small or mid-sized sports-utility or cross-over vehicle, or a small-midsize SUV, or a Mini Van powered by a 4 cylinder turbocharged engine, direct fuel injection, 6-speed MT or AT & 7 DCT.	Power-split HEV System Power: 132.6kW ICE Power: 108.3kW (I4 -> DS I4) Traction Motor: 88.7kW Generator: 62.2kW Li-Ion Battery: 199V, 1.053 kWh	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 2,336	€ 5,891	€ 4,532	€ 3,391	€ 2,788
	6	0506	Large sports-utility vehicles, typically powered by a 8 cylinder naturally aspirated engine, direct fuel injection, ≥ 6-speed AT.	n/a	Large SUV	VW Touareg	---	---	---	---	---

Table C-6: P2 Hybrid Electric Vehicle Case Study Results

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
P2 HEV	1	0700	Subcompact car typically powered by an inline 4 cylinder engine, naturally aspirated, port fuel injection, 5-speed manual transmission (MT).	P2 HEV System Power: 74.7kW ICE Power: 59.8kW (I4 -> I3) Traction Motor: 14.9kW Li-Ion Battery: 140V, 0.743kWh	Subcompact Passenger Vehicle	VW Polo	€ 1,704	€ 4,391	€ 3,355	€ 2,502	€ 2,045
	2	0701	Compact or small car typically powered by an inline 4 cylinder engine, naturally aspirated, port fuel injection, 6-speed manual transmission or 7-speed dual clutch transmission (DCT).	P2 HEV System Power: 90kW ICE Power: 72kW (I4 -> DS I4) Traction Motor: 18kW Li-Ion Battery: 162V, 0.857kWh	Compact or Small Passenger Vehicle	VW Golf	€ 1,915	€ 4,914	€ 3,760	€ 2,806	€ 2,297
	3	0702	A midsize passenger car typically powered by a 4 cylinder turbocharged, direct fuel injection, 6-speed MT and AT or 7-speed DCT, Start/Stop system.	P2 HEV System Power: 117kW ICE Power: 93.6kW (I4 -> DS I4) Traction Motor: 23.4kW Li-Ion Battery: 188V, 0.994kWh	Midsize Passenger Vehicle	VW Passat	€ 2,080	€ 5,398	€ 4,115	€ 3,067	€ 2,502
	4	0703	A midsize or large passenger car typically powered by 4 and 6 cylinder turbocharged, direct fuel injection, 6-speed MT or ≥ 6 speed AT.	P2 HEV System Power: 174.8kW ICE Power: 139.9kW (V6 -> I4) Traction Motor: 35.0W Li-Ion Battery: 211V, 1.118 kWh	Midsize or Large Passenger Vehicle	VW Sharan	€ 1,947	€ 5,382	€ 4,023	€ 2,972	€ 2,382
	5	0705	A small or mid-sized sports-utility or cross-over vehicle, or a small-midsize SUV, or a Mini Van powered by a 4 cylinder turbocharged engine, direct fuel injection, 6-speed MT or AT & 7 DCT.	P2 HEV System Power: 132.6kW ICE Power: 106.1kW (I4 -> DS I4) Traction Motor: 26.5kW Li-Ion Battery: 199V, 1.053kWh	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 2,164	€ 5,621	€ 4,284	€ 3,192	€ 2,603
	6	0706	Large sports-utility vehicles, typically powered by a 8 cylinder naturally aspirated engine, direct fuel injection, ≥ 6-speed AT.	P2 HEV System Power: 271.8kW ICE Power: 271.8 kW (No Change to V8) Traction Motor: 54.3 kW Li-Ion Battery: 269V, 1.427kWh	Large SUV	VW Touareg	€ 2,756	€ 7,156	€ 5,454	€ 4,064	€ 3,316

Table C-7: Electrical Air Conditioning Compressor Case Study Results

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Electrical Air Conditioning Compressor Subsystem	1	0600	Mechanical Air Conditioning Compressor Subsystem	Electrical Air Conditioning Compressor Subsystem	Subcompact Passenger Vehicle	VW Polo	€ 102	€ 159	€ 146	€ 117	€ 109
	2	0601	Mechanical Air Conditioning Compressor Subsystem	Electrical Air Conditioning Compressor Subsystem	Compact or Small Passenger Vehicle	VW Golf	€ 106	€ 166	€ 153	€ 123	€ 114
	3	0602	Mechanical Air Conditioning Compressor Subsystem	Electrical Air Conditioning Compressor Subsystem	Midsize Passenger Vehicle	VW Passat	€ 111	€ 174	€ 161	€ 129	€ 120
	4	0603	Mechanical Air Conditioning Compressor Subsystem	Electrical Air Conditioning Compressor Subsystem	Midsize or Large Passenger Vehicle	VW Sharan	€ 115	€ 180	€ 166	€ 133	€ 124
	5	0604	Mechanical Air Conditioning Compressor Subsystem	Electrical Air Conditioning Compressor Subsystem	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 118	€ 184	€ 169	€ 136	€ 126
	6	0605	Mechanical Air Conditioning Compressor Subsystem	Electrical Air Conditioning Compressor Subsystem	Large SUV	VW Touareg	€ 135	€ 212	€ 195	€ 157	€ 146

C.2 Phase 2 Technologies Evaluated

A summary of the baseline and new technology configurations evaluated in the original Phase 2 analysis, and reference to the corresponding cost summary tables, is summarized below in.

Table C-8: Advance Powertrain Technologies Evaluated in the Phase 2 Analysis

Case Study ID	Baseline Technology Configuration	New Technology Configuration	Cost Summary Table
20**	Conventional Diesel Engine	Downsized Conventional Diesel Engine (e.g. I4-I3, I6-I4, V8-I6)	C-9
21**	Conventional Diesel Engine with 1800 Bar Fuel Injection Subsystem	Conventional Diesel Engine Upgraded with 2500 Bar Fuel Injection Subsystem	C-10
22**	Diesel Engine with Conventional Valvetrain Subsystem	Diesel Engine Upgraded with Discrete Variable Valve Timing and Lift (VVTL) Valvetrain subsystem	C-11
23**	Conventional Diesel Engine with a Cooled High Pressure Exhaust Gas Recirculation (EGR) Subsystem	Conventional Diesel Engine Upgraded with a High Pressure, Low Pressure Cooled High EGR Subsystem	C-12
31**	Conventional Gasoline Engine with a Uncooled Low Pressure EGR Subsystem	Conventional Gasoline Engine Upgraded with a Cooled Low Pressure EGR Subsystem	C-13
32**	Conventional Gasoline Engine with no EGR Subsystem	Conventional Gasoline Engine Upgraded with a Cooled Low Pressure EGR Subsystem	C-14
26**	6-Speed Manual Transmission	6-Speed Dry Dual Clutch Transmission (DCT)	C-15
30**	Conventional Powertrain Vehicle (Manual Transmission)	Conventional Powertrain Vehicle ((Manual Transmission) Upgraded with a Belt-Driven Starter Generator (BSG) Start-Stop System	C-16

Table C-9: Diesel Engine Downsizing Case Studies

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Diesel Engine Downsizing	2	2000B	Diesel I4 ICE Ave. Displacement = 1.2-1.4L Ave. Power = 62.5kW (85HP) Ave. Torque = 201N*m (148lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Downsized to Diesel I3 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Subcompact Passenger Vehicle	VW Polo	(€ 284)	(€ 215)	(€ 215)	(€ 229)	(€ 229)
	3	2001	Diesel I4 ICE Ave. Displacement = 1.6L Ave. Power = 78.6kW (107HP) Ave. Torque = 246N*m (181lb*ft) Typical Transmission Type: 5 or 6 speed MT or DCT Curb Weight: 1271kg (2803lb)	Downsized to Diesel I3 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Compact or Small Passenger Vehicle	VW Golf	(€ 290)	(€ 220)	(€ 220)	(€ 234)	(€ 234)
	4	2002	Diesel I4 ICE Ave. Displacement = 2.0L Ave. Power = 104kW (141HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1496kg (3299lb)	Downsized to Diesel I3 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Midsize Passenger Vehicle	VW Passat	(€ 303)	(€ 229)	(€ 229)	(€ 245)	(€ 245)
	5	2003A	Diesel I4 ICE Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Downsized to Diesel I3 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Midsize or Large Passenger Vehicle	VW Sharan	(€ 303)	(€ 229)	(€ 229)	(€ 245)	(€ 245)
	6	2003B	Diesel I6 ICE Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Downsized to Diesel I4 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Midsize or Large Passenger Vehicle	VW Sharan	(€ 437)	(€ 332)	(€ 332)	(€ 353)	(€ 353)
	7	2005	Diesel I4 ICE Ave. Displacement = 2.0-3.0L Ave. Power = 117.6W (160HP) Ave. Torque = 336N*m (248lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1590kg (3505lb)	Downsized to Diesel I3 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Small or Midsize SUV/COV or Mini Van	VW Tiguan	(€ 303)	(€ 229)	(€ 229)	(€ 245)	(€ 245)
	9	2006B	Diesel V8 ICE Ave. Displacement = 3.0 -4.2L Ave. Power = 213kW (290HP) Ave. Torque = 623N*m (460lb*ft) Typical Transmission Type: 8-Speed AT Curb Weight: 2207kg (4866lb)	Downsized to Diesel I6 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Large SUV	VW Touareg	(€ 442)	(€ 335)	(€ 335)	(€ 357)	(€ 357)

Table C-10: 2500 Bar Diesel Fuel Injection System Case Study Results

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
High Pressure Fuel Injection, Diesel Engine	1	2100A	Diesel I3 ICE 1800 Bar Fuel Injection System Ave. Displacement = 1.0L Ave. Power = 62.5kW (85HP) Ave. Torque = 201N*m (148lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Diesel I3 ICE Upgraded to 2500 Bar Fuel Injection System	Subcompact Passenger Vehicle	VW Polo	€ 9	€ 12	€ 11	€ 9	€ 9
	2	2100B	Diesel I4 ICE 1800 Bar Fuel Injection System Ave. Displacement = 1.2-1.4L Ave. Power = 62.5kW (85HP) Ave. Torque = 201N*m (148lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Diesel I4 ICE Upgraded to 2500 Bar Fuel Injection System	Subcompact Passenger Vehicle	VW Polo	€ 11	€ 16	€ 14	€ 12	€ 12
	3	2101	Diesel I4 ICE 1800 Bar Fuel Injection System Ave. Displacement = 1.6L Ave. Power = 78.6kW (107HP) Ave. Torque = 246N*m (181lb*ft) Typical Transmission Type: 5 or 6 speed MT or DCT Curb Weight: 1271kg (2803lb)	Diesel I4 ICE Upgraded to 2500 Bar Fuel Injection System	Compact or Small Passenger Vehicle	VW Golf	€ 11	€ 16	€ 14	€ 12	€ 12
	4	2102	Diesel I4 ICE 1800 Bar Fuel Injection System Ave. Displacement = 2.0L Ave. Power = 104kW (141HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1496kg (3299lb)	Diesel I4 ICE Upgraded to 2500 Bar Fuel Injection System	Midsize Passenger Vehicle	VW Passat	€ 11	€ 16	€ 14	€ 12	€ 12
	6	2103B	Diesel I6 ICE 1800 Bar Fuel Injection System Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Diesel I6 ICE Upgraded to 2500 Bar Fuel Injection System	Midsize or Large Passenger Vehicle	VW Sharan	€ 17	€ 23	€ 21	€ 18	€ 17
	7	2105	Diesel I4 ICE 1800 Bar Fuel Injection System Ave. Displacement = 2.0-3.0L Ave. Power = 117.6W (160HP) Ave. Torque = 336N*m (248lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1590kg (3505lb)	Diesel I4 ICE Upgraded to 2500 Bar Fuel Injection System	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 11	€ 16	€ 14	€ 12	€ 12
	9	2106B	Diesel V8 ICE 1800 Bar Fuel Injection System Ave. Displacement = 3.0-4.2L Ave. Power = 213kW (290HP) Ave. Torque = 623N*m (460lb*ft) Typical Transmission Type: 8-Speed AT Curb Weight: 2207kg (4866lb)	Diesel V8 ICE Upgraded to 2500 Bar Fuel Injection System	Large SUV	VW Touareg	€ 22	€ 31	€ 28	€ 24	€ 23

Table C-11: Discrete Variable Valve Lift and Timing Valvetrain (Diesel Engine) Case Study Results

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Variable Valve Timing and Lift	1	2200A	Diesel I3 ICE Conventional Valvetrain Ave. Displacement = 1.0L Ave. Power = 62.5kW (85HP) Ave. Torque = 201N*m (148lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Diesel I3 ICE Upgraded with Discrete Variable Valve Timing and Lift	Subcompact Passenger Vehicle	VW Polo	€ 89	€ 133	€ 121	€ 106	€ 98
	3	2201	Diesel I4 ICE Conventional Valvetrain Ave. Displacement = 1.6L Ave. Power = 78.6kW (107HP) Ave. Torque = 246N*m (181lb*ft) Typical Transmission Type: 5 or 6 speed MT or DCT Curb Weight: 1271kg (2803lb)	Diesel I4 ICE Upgraded with Discrete Variable Valve Timing and Lift	Compact or Small Passenger Vehicle	VW Golf	€ 96	€ 143	€ 130	€ 114	€ 105
	4	2202	Diesel I4 ICE Conventional Valvetrain Ave. Displacement = 2.0L Ave. Power = 104kW (141HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1496kg (3299lb)	Diesel I4 ICE Upgraded with Discrete Variable Valve Timing and Lift	Midsize Passenger Vehicle	VW Passat	€ 96	€ 143	€ 130	€ 114	€ 105
	5	2203A	Diesel I4 ICE Conventional Valvetrain Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Diesel I4 ICE Upgraded with Discrete Variable Valve Timing and Lift	Midsize or Large Passenger Vehicle	VW Sharan	€ 96	€ 143	€ 130	€ 114	€ 105
	6	2203B	Diesel I6 ICE Conventional Valvetrain Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Diesel I6 ICE Upgraded with Discrete Variable Valve Timing and Lift	Midsize or Large Passenger Vehicle	VW Sharan	€ 112	€ 167	€ 152	€ 133	€ 123
	7	2205	Diesel I4 ICE Conventional Valvetrain Ave. Displacement = 2.0-3.0L Ave. Power = 117.6W (160HP) Ave. Torque = 336N*m (248lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1590kg (3505lb)	Diesel I4 ICE Upgraded with Discrete Variable Valve Timing and Lift	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 96	€ 143	€ 130	€ 114	€ 105
	9	2206B	Diesel V8 ICE Conventional Valvetrain Ave. Displacement = 3.0-4.2L Ave. Power = 213kW (290HP) Ave. Torque = 623N*m (460lb*ft) Typical Transmission Type: 8-Speed AT Curb Weight: 2207kg (4866lb)	Diesel V8 ICE Upgraded with Discrete Variable Valve Timing and Lift	Large SUV	VW Touareg	€ 192	€ 286	€ 261	€ 227	€ 210

Table C-12: High Pressure, Low Pressure Cooled EGR (Diesel Engine) Case Study Results

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Calculated Incremental Direct Manufacturing Cost 2010/2011 Production Year	Net Incremental Manufacturing Costs (Direct and Indirect Costs) with Applicable Learning Applied			
								2012	2016	2020	2025
High Pressure, Cooled Low Pressure EGR	1	2300A	Diesel I3 ICE Cooled High Pressure EGR Ave. Displacement = 1.0L Ave. Power = 62.5kW (85HP) Ave. Torque = 201N*m (148lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Diesel I3 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Subcompact Passenger Vehicle	VW Polo	€ 89	€ 123	€ 112	€ 97	€ 90
	3	2301	Diesel I4 ICE Cooled High Pressure EGR Ave. Displacement = 1.6L Ave. Power = 78.6kW (107HP) Ave. Torque = 246N*m (181lb*ft) Typical Transmission Type: 5 or 6 speed MT or DCT Curb Weight: 1271kg (2803lb)	Diesel I4 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Compact or Small Passenger Vehicle	VW Golf	€ 89	€ 123	€ 112	€ 97	€ 90
	4	2302	Diesel I4 ICE Cooled High Pressure EGR Ave. Displacement = 2.0L Ave. Power = 104kW (141HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1496kg (3299lb)	Diesel I4 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Midsize Passenger Vehicle	VW Passat	€ 89	€ 123	€ 112	€ 97	€ 90
	5	2303A	Diesel I4 ICE Cooled High Pressure EGR Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Diesel I4 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Midsize or Large Passenger Vehicle	VW Sharan	€ 89	€ 123	€ 112	€ 97	€ 90
	6	2303B	Diesel I6 ICE Cooled High Pressure EGR Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Diesel I6 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Midsize or Large Passenger Vehicle	VW Sharan	€ 89	€ 123	€ 112	€ 97	€ 90
	7	2305	Diesel I4 ICE Cooled High Pressure EGR Ave. Displacement = 2.0-3.0L Ave. Power = 117.6W (160HP) Ave. Torque = 336N*m (248lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1590kg (3505lb)	Diesel I4 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 89	€ 123	€ 112	€ 97	€ 90
	9	2306B	Diesel V8 ICE Cooled High Pressure EGR Ave. Displacement = 3.0-4.2L Ave. Power = 213kW (290HP) Ave. Torque = 623N*m (460lb*ft) Typical Transmission Type: 8-Speed AT Curb Weight: 2207kg (4866lb)	Diesel V8 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Large SUV	VW Touareg	€ 88	€ 123	€ 112	€ 97	€ 90

Table C-13: Cooled Low Pressure EGR (Gasoline Engine) Case Study Results

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Gasoline, Cooled Low Pressure EGR (Compared to Uncooled Low Pressure EGR)	1	3100A	Gasoline I3 ICE Uncooled Low Pressure EGR Ave. Displacement = 1.2-1.4L Ave. Power = 74kW (100HP) Ave. Torque = 146N*m (108lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Gasoline I3 ICE Upgraded with Cooled Low Pressure EGR System	Subcompact Passenger Vehicle	VW Polo	€ 43	€ 60	€ 55	€ 52	€ 44
	3	3101	Gasoline I4 ICE Uncooled Low Pressure EGR Ave. Displacement = 1.4-1.6L Ave. Power = 89kW (121HP) Ave. Torque = 179N*m (132lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1271kg (2803lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Compact or Small Passenger Vehicle	VW Golf	€ 47	€ 65	€ 59	€ 56	€ 48
	4	3102	Gasoline I4 ICE Uncooled Low Pressure EGR Ave. Displacement = 1.6-2.0L Ave. Power = 115kW (157HP) Ave. Torque = 236N*m (174lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1496kg (3299lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Midsize Passenger Vehicle	VW Passat	€ 52	€ 73	€ 66	€ 63	€ 53
	5	3103A	Gasoline I4 ICE Uncooled Low Pressure EGR Ave. Displacement = 2.0-3.0L Ave. Power = 172kW (234HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Midsize or Large Passenger Vehicle	VW Sharan	€ 65	€ 90	€ 82	€ 78	€ 66
	6	3103B	Gasoline I6 ICE Uncooled Low Pressure EGR Ave. Displacement = 2.0-3.0L Ave. Power = 172kW (234HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Gasoline I6 ICE Upgraded with Cooled Low Pressure EGR System	Midsize or Large Passenger Vehicle	VW Sharan	€ 65	€ 90	€ 82	€ 78	€ 66
	7	3105	Gasoline I4 ICE Uncooled Low Pressure EGR Ave. Displacement = 1.2-3.0L Ave. Power = 131 kW (178HP) Ave. Torque = 264N*m (195lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1590kg (3505lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 56	€ 78	€ 71	€ 67	€ 57
	9	3106B	Gasoline V8 ICE Uncooled Low Pressure EGR Ave. Displacement = 3.0-5.5 Ave. Power = 268 kW (364HP) Ave. Torque = 491N*m (362lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 2207kg (4867lb)	Gasoline V8 ICE Upgraded with Cooled Low Pressure EGR System	Large SUV	VW Touareg	€ 87	€ 120	€ 110	€ 104	€ 88

Table C-14: Cooled Low Pressure EGR Compared to ICE with No EGR (Gasoline Engine) Case Study Results

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Gasoline, Cooled Low Pressure EGR (Compare to ICE with no EGR)	1	3200A	Gasoline I3 ICE No EGR Ave. Displacement = 1.2-1.4L Ave. Power = 74kW (100HP) Ave. Torque = 146N*m (108lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Gasoline I3 ICE Upgraded with Cooled Low Pressure EGR System	Subcompact Passenger Vehicle	VW Polo	€ 74	€ 102	€ 94	€ 88	€ 75
	3	3201	Gasoline I4 ICE No EGR Ave. Displacement = 1.4-1.6L Ave. Power = 89kW (121HP) Ave. Torque = 179N*m (132lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1271kg (2803lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Compact or Small Passenger Vehicle	VW Golf	€ 77	€ 107	€ 98	€ 92	€ 79
	4	3202	Gasoline I4 ICE No EGR Ave. Displacement = 1.6-2.0L Ave. Power = 115kW (157HP) Ave. Torque = 236N*m (174lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1496kg (3299lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Midsize Passenger Vehicle	VW Passat	€ 83	€ 115	€ 105	€ 99	€ 85
	5	3203A	Gasoline I4 ICE No EGR Ave. Displacement = 2.0-3.0L Ave. Power = 172kW (234HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Midsize or Large Passenger Vehicle	VW Sharan	€ 96	€ 133	€ 121	€ 114	€ 98
	6	3203B	Gasoline I6 ICE No EGR Ave. Displacement = 2.0-3.0L Ave. Power = 172kW (234HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Gasoline I6 ICE Upgraded with Cooled Low Pressure EGR System	Midsize or Large Passenger Vehicle	VW Sharan	€ 96	€ 133	€ 121	€ 114	€ 98
	7	3205	Gasoline I4 ICE No EGR Ave. Displacement = 1.2-3.0L Ave. Power = 131 kW (178HP) Ave. Torque = 264N*m (195lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1590kg (3505lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 87	€ 120	€ 110	€ 103	€ 88
	9	3206B	Gasoline V8 ICE No EGR Ave. Displacement = 3.0-5.5 Ave. Power = 268 kW (364HP) Ave. Torque = 491N*m (362lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 2207kg (4867lb)	Gasoline V8 ICE Upgraded with Cooled Low Pressure EGR System	Large SUV	VW Touareg	€ 117	€ 163	€ 149	€ 140	€ 120

Table C-15: 6-Speed Dry Dual Clutch Transmission Case Study Results

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Dry Dual Clutch Transmission	1	2600A	Diesel I3 ICE Ave. Displacement = 1.0L Ave. Power = 62.5kW (85HP) Ave. Torque = 201N*m (148lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1084kg (2390lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Subcompact Passenger Vehicle	VW Polo	€ 288	€ 400	€ 365	€ 317	€ 294
	3	2601	Diesel I4 ICE Ave. Displacement = 1.6L Ave. Power = 78.6kW (107HP) Ave. Torque = 246N*m (181lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1271kg (2803lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Compact or Small Passenger Vehicle	VW Golf	€ 291	€ 404	€ 369	€ 321	€ 297
	4	2602	Diesel I4 ICE Ave. Displacement = 2.0L Ave. Power = 104kW (141HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1496kg (3299lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Midsize Passenger Vehicle	VW Passat	€ 297	€ 412	€ 377	€ 327	€ 303
	5	2603A	Diesel I4 ICE Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Midsize or Large Passenger Vehicle	VW Sharan	€ 304	€ 422	€ 385	€ 334	€ 310
	6	2603B	Diesel I6 ICE Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Midsize or Large Passenger Vehicle	VW Sharan	€ 304	€ 422	€ 385	€ 334	€ 310
	7	2605	Diesel I4 ICE Ave. Displacement = 2.0-3.0L Ave. Power = 117.6W (160HP) Ave. Torque = 336N*m (248lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1590kg (3505lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 298	€ 414	€ 378	€ 328	€ 304
	9	2606B	Diesel V8 ICE Ave. Displacement = 3.0 -4.2L Ave. Power = 213kW (290HP) Ave. Torque = 623N*m (460lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 2207kg (4866lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Large SUV	VW Touareg	€ 320	€ 443	€ 405	€ 352	€ 326

Table C-16: Belt-Driven, Starter-Generator (BSG) Start-Stop Hybrid Electric Vehicle Technology

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Start-Stop Hybrid Electric Vehicle Technology	2	3000B	Gasoline I4 ICE Conventional Powertrain Ave. Displacement = 1.2-1.4L Ave. Power = 74kW (100HP) Ave. Torque = 146N*m (108lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Gasoline I4 ICE, Manual Transmission, upgraded with Belt-Driven, Starter-Generator (BSG) System.	Subcompact Passenger Vehicle	VW Polo	€ 298	€ 589	€ 414	€ 349	€ 311
	3	3001	Gasoline I4 ICE Conventional Powertrain Ave. Displacement = 1.4-1.6L Ave. Power = 89kW (121HP) Ave. Torque = 179N*m (132lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1271kg (2803lb)	Gasoline I4 ICE, Manual Transmission, Upgraded with Belt-Driven, Starter-Generator (BSG) System.	Compact or Small Passenger Vehicle	VW Golf	€ 311	€ 613	€ 431	€ 364	€ 324
	4	3002	Gasoline I4 ICE Conventional Powertrain Ave. Displacement = 1.6-2.0L Ave. Power = 115kW (157HP) Ave. Torque = 236N*m (174lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1496kg (3299lb)	Gasoline I4 ICE, Manual Transmission, Upgraded with Belt-Driven, Starter-Generator (BSG) System.	Midsize Passenger Vehicle	VW Passat	€ 329	€ 650	€ 456	€ 385	€ 343
	6	3003B	Gasoline I6 or V6 ICE Conventional Powertrain Ave. Displacement = 2.0-3.0L Ave. Power = 172kW (234HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Gasoline I6 or V6 ICE, Manual Transmission, Upgraded with Belt-Driven, Starter-Generator (BSG) System.	Midsize or Large Passenger Vehicle	VW Sharan	€ 352	€ 695	€ 488	€ 412	€ 367
	7	3005	Gasoline I4 ICE Conventional Powertrain Ave. Displacement = 1.2-3.0L Ave. Power = 131 kW (178HP) Ave. Torque = 264N*m (195lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1590kg (3505lb)	Gasoline I4 ICE, Manual Transmission, Upgraded with Belt-Driven, Starter-Generator (BSG) System.	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 337	€ 666	€ 468	€ 395	€ 351
	9	3006B	Gasoline V8 ICE Conventional Powertrain Ave. Displacement = 3.0-5.5L Ave. Power = 268 kW (364HP) Ave. Torque = 491N*m (362lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 2207kg (4867lb)	Gasoline V8 ICE, Manual Transmission, Upgraded with Belt-Driven, Starter-Generator (BSG) System.	Large SUV	VW Touareg	€ 449	€ 887	€ 623	€ 526	€ 468

D. Phase 1 and Phase 2 Case Study Results Reevaluated With Average Eastern Europe Labor Rate Assumption

As discussed in **Section B.2** all case studies, originally evaluated in Phase 1 and Phase 2, were reevaluated with a reduced labor rate assumption. The labor rate reduction was based on an average Eastern Europe reduction relative to Germany. In **Section D.1** and **D.2**, the Phase 1 and Phase 2 results have been modified to account for the labor rate reduction.

D.1 Phase 1 Technologies Evaluated with Eastern Europe Labor Rate Assumption

A summary of the baseline and new technology configurations evaluated in the Phase 1, updated with the Eastern Europe labor rate assumption, is summarized below in Table D-1. The table, similar to the one found in Section C.1, has been modified with the new Cost Summary Table references.

Table D-1: Advance Powertrain Technologies, Evaluated in the Phase 1 Analysis, with Eastern Europe Labor Rate Assumption

Case Study ID	Baseline Technology Configuration	New Technology Configuration	Cost Summary Table
01**	Naturally Aspirated (NA), Port Fuel Injected (PFI), Gasoline Internal Combustion Engine (ICE)	Downsized (DS), Turbocharged (Turbo), Direct Injection (DI) Gasoline Internal Combustion Engine (ICE)	D-2
02**	Dual Overhead Cam (DOHC), NA, PFI, Dual-Variable Valve Timing (D-VVT), Gasoline ICE	Single Overhead Cam (SOHC), NA, PFI, Multi-Air Variable Valve Timing and Lift (VVTL), Gasoline ICE	D-2
08**	5-Speed Automatic Transmission	6-Speed Automatic Transmission	D-3
10**	6-Speed Automatic Transmission	8-Speed Automatic Transmission	D-3
09**	6-Speed Automatic Transmission	6-Speed Dual Clutch Transmission	D-3
04**	Conventional Powertrain Vehicle	Conventional Powertrain Vehicle Upgraded with a Belt Alternator Starter (BAS) Start-Stop System	D-4
05**	Conventional Powertrain Vehicle	Power-Split Hybrid Electric Vehicle	D-5
07**	Conventional Powertrain Vehicle	P2 Hybrid Electric Vehicle	D-6
06**	Mechanical Air Conditioning Compressor System	Electical Air Conditioning Compressor System	D-7

Table D-2: Downsized, Turbocharged, Direct Injection Gasoline Engine & Multi-Air Variable Valve Timing and Lift Valvetrain Subsystem Case Study Results

*** Eastern Europe Labor Rate Substitution ***

Technology ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)				
							2012	2016	2020	2025	
Downsized, Turbocharged, Gasoline Direct Injection Internal Combustion Engines											
Engine	1	0100	1.4L, I4, 4V, DOHC, NA, PFI, dVVT, ICE	1.0L, I3, 4V, DOHC, Turbo, GDI, dVVT, ICE	Subcompact Passenger Vehicle	VW Polo	€ 169	€ 311	€ 279	€ 225	€ 203
	2	0101	1.6L, I4, 4V, DOHC, NA, PFI, dVVT, ICE	1.2L, I4, 4V, DOHC, Turbo, GDI, dVVT, ICE	Compact or Small Passenger Vehicle	VW Golf	€ 265	€ 376	€ 343	€ 296	€ 273
	3	0102	2.4L, I4, 4V, DOHC, NA, PFI, dVVT, ICE	1.6L, I4, 4V, DOHC, Turbo, GDI, dVVT, ICE	Midsize Passenger Vehicle	VW Passat	€ 307	€ 445	€ 406	€ 348	€ 321
	4	0103	3.0L, V6, 4V, DOHC, NA, PFI, dVVT, ICE	2.0L, I4, 4V, DOHC, Turbo, GDI, dVVT, ICE	Midsize or Large Passenger Vehicle	VW Sharan	€ 33	€ 320	€ 273	€ 174	€ 143
	5	0106	5.4L, V8, 3V, SOHC, NA, PFI, sVVT, ICE	3.5L V6, 4V, DOHC, Turbo, GDI, dVVT, ICE	Large SUV	VW Touareg	€ 532	€ 813	€ 738	€ 623	€ 572
Variable Valve Timing and Lift, Fiat MultiAir System											
	6	0200	1.4L, I4, 4V, DOHC, NA, PFI, dVVT, ICE	1.4L, I4, 4V-MultiAir, SOHC, NA, PFI, ICE	Subcompact Passenger Vehicle	VW Polo	€ 87	€ 129	€ 118	€ 102	€ 95

Table D-3: 6-Speed Automatic Transmission, 8-Speed Automatic Transmission, and 6-Speed Wet Dual Clutch Transmission Case Study Results

*** Eastern Europe Labor Rate Substitution ***

Technology ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)				
							2012	2016	2020	2025	
Transmissions	1	0802	5-Speed AT	6-Speed AT	Midsize or Large Passenger Vehicle	VW Sharan	(€ 64)	(€ 48)	(€ 48)	(€ 51)	(€ 51)
	2	0803	6-Speed AT	8-Speed AT	Large SUV	VW Touareg	€ 44	€ 61	€ 56	€ 49	€ 45
	3	0902	6-Speed AT	6-Speed Wet DCT	Midsize or Large Passenger Vehicle	VW Sharan	(€ 60)	(€ 37)	(€ 37)	(€ 43)	(€ 43)

Table D-4: Belt Alternator Starter (BAS) Start-Stop System Case Study Results
 *** Eastern Europe Labor Rate Substitution ***

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Start-Stop HEV	1	0402	Conventional Powertrain >I4 Gasoline ICE, 4V, DOHC, NA, PFI, VVT >4-Speed AT	Belt Alternator Starter (BAS) - HEV (Brake Regen & Launch Assist) >I4 Gasoline ICE, 4V, DOHC, NA, PFI, VVT >4-Speed AT >Electric Generator/Starter 14.5kW >Battery: 36V, 18.4Ah NiMH	Midsize Passenger Vehicle	VW Passat	€ 951	€ 1,879	€ 1,320	€ 1,114	€ 992

Table D-5: Power-Split Hybrid Electric Vehicle Case Study Results
 *** Eastern Europe Labor Rate Substitution ***

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Power-Split HEV	1	0500	Subcompact car typically powered by an inline 4 cylinder engine, naturally aspirated, port fuel injection, 5-speed manual transmission (MT).	Power-split HEV System Power: 74.7kW ICE Power: 61.1kW (I4 -> I3) Traction Motor: 50kW Generator: 35.1kW Li-Ion Battery: 140V, 0.743kWh	Subcompact Passenger Vehicle	VW Polo	€ 1,556	€ 3,869	€ 2,990	€ 2,242	€ 1,851
	2	0501	Compact or small car typically powered by an inline 4 cylinder engine, naturally aspirated, port fuel injection, 6-speed manual transmission or 7-speed dual clutch transmission (DCT).	Power-split HEV System Power: 90kW ICE Power: 73.6kW (I4 - DS I4) Traction Motor: 60.2kW Generator: 42.3kW Li-Ion Battery: 162V, 0.857kWh	Compact or Small Passenger Vehicle	VW Golf	€ 1,732	€ 4,299	€ 3,324	€ 2,493	€ 2,059
	3	0502	A midsize passenger car typically powered by a 4 cylinder turbocharged, direct fuel injection, 6-speed MT and AT or 7-speed DCT, Start/Stop system.	Power-split HEV System Power: 117kW ICE Power: 95.6kW (I4 -> DS I4) Traction Motor: 78.3kW Generator: 55kW Li-Ion Battery: 188V, 0.994kWh	Midsize Passenger Vehicle	VW Passat	€ 1,905	€ 4,751	€ 3,668	€ 2,749	€ 2,267
	4	5403	A midsize or large passenger car typically powered by 4 and 6 cylinder turbocharged, direct fuel injection, 6-speed MT or ≥ 6 speed AT.	Power-split HEV System Power: 174.8kW ICE Power: 142.8kW (V6 -> I4) Traction Motor: 116.9kW Generator: 82.1kW Li-Ion Battery: 211V, 1.118kWh	Midsize or Large Passenger Vehicle	VW Sharan	€ 1,861	€ 4,837	€ 3,685	€ 2,746	€ 2,239
	5	0505	A small or mid-sized sports-utility or cross-over vehicle, or a small-midsize SUV, or a Mini Van powered by a 4 cylinder turbocharged engine, direct fuel injection, 6-speed MT or AT & 7 DCT.	Power-split HEV System Power: 132.6kW ICE Power: 108.3kW (I4 -> DS I4) Traction Motor: 88.7kW Generator: 62.2kW Li-Ion Battery: 199V, 1.053 kWh	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 1,996	€ 4,968	€ 3,838	€ 2,877	€ 2,374
	6	n/a	Large sports-utility vehicles, typically powered by a 8 cylinder naturally aspirated engine, direct fuel injection, ≥ 6-speed AT.	n/a	Large SUV	VW Touareg	n/a	---	---	---	---

Table D-6: P2 Hybrid Electric Vehicle Case Study Results

***** Eastern Europe Labor Rate Substitution *****

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
P2 HEV	1	0700	Subcompact car typically powered by an inline 4 cylinder engine, naturally aspirated, port fuel injection, 5-speed manual transmission (MT).	P2 HEV System Power: 74.7kW ICE Power: 59.8kW (I4 -> I3) Traction Motor: 14.9kW Li-Ion Battery: 140V, 0.743kWh	Subcompact Passenger Vehicle	VW Polo	€ 1,467	€ 3,729	€ 2,862	€ 2,139	€ 1,755
	2	0701	Compact or small car typically powered by an inline 4 cylinder engine, naturally aspirated, port fuel injection, 6-speed manual transmission or 7-speed dual clutch transmission (DCT).	P2 HEV System Power: 90kW ICE Power: 72kW (I4 -> DS I4) Traction Motor: 18kW Li-Ion Battery: 162V, 0.857kWh	Compact or Small Passenger Vehicle	VW Golf	€ 1,637	€ 4,151	€ 3,188	€ 2,383	€ 1,957
	3	0702	A midsize passenger car typically powered by a 4 cylinder turbocharged, direct fuel injection, 6-speed MT and AT or 7-speed DCT, Start/Stop system.	P2 HEV System Power: 117kW ICE Power: 93.6kW (I4 -> DS I4) Traction Motor: 23.4kW Li-Ion Battery: 188V, 0.994kWh	Midsize Passenger Vehicle	VW Passat	€ 1,777	€ 4,551	€ 3,484	€ 2,601	€ 2,130
	4	0703	A midsize or large passenger car typically powered by 4 and 6 cylinder turbocharged, direct fuel injection, 6-speed MT or ≥ 6 speed AT.	P2 HEV System Power: 174.8kW ICE Power: 139.9kW (V6 -> I4) Traction Motor: 35.0W Li-Ion Battery: 211V, 1.118 kWh	Midsize or Large Passenger Vehicle	VW Sharan	€ 1,628	€ 4,473	€ 3,349	€ 2,476	€ 1,988
	5	0705	A small or mid-sized sports-utility or cross-over vehicle, or a small-midsize SUV, or a Mini Van powered by a 4 cylinder turbocharged engine, direct fuel injection, 6-speed MT or AT & 7 DCT.	P2 HEV System Power: 132.6kW ICE Power: 106.1kW (I4 -> DS I4) Traction Motor: 26.5kW Li-Ion Battery: 199V, 1.053kWh	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 1,848	€ 4,737	€ 3,625	€ 2,706	€ 2,215
	6	0706	Large sports-utility vehicles, typically powered by a 8 cylinder naturally aspirated engine, direct fuel injection, ≥ 6-speed AT.	P2 HEV System Power: 271.8kW ICE Power: 271.8 kW (No Change to V8) Traction Motor: 54.3 kW Li-Ion Battery: 269V, 1.427kWh	Large SUV	VW Touareg	€ 2,345	€ 6,003	€ 4,596	€ 3,431	€ 2,810

Table D-7: Electrical Air Conditioning Compressor Case Study Results
***** Eastern Europe Labor Rate Substitution *****

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Electrical Air Conditioning Compressor Subsystem	1	0600	Mechanical Air Conditioning Compressor Subsystem	Electrical Air Conditioning Compressor Subsystem	Subcompact Passenger Vehicle	VW Polo	€ 100	€ 156	€ 144	€ 115	€ 107
	2	0601	Mechanical Air Conditioning Compressor Subsystem	Electrical Air Conditioning Compressor Subsystem	Compact or Small Passenger Vehicle	VW Golf	€ 103	€ 161	€ 149	€ 119	€ 111
	3	0602	Mechanical Air Conditioning Compressor Subsystem	Electrical Air Conditioning Compressor Subsystem	Midsize Passenger Vehicle	VW Passat	€ 109	€ 170	€ 157	€ 126	€ 117
	4	0603	Mechanical Air Conditioning Compressor Subsystem	Electrical Air Conditioning Compressor Subsystem	Midsize or Large Passenger Vehicle	VW Sharan	€ 113	€ 176	€ 162	€ 130	€ 121
	5	0605	Mechanical Air Conditioning Compressor Subsystem	Electrical Air Conditioning Compressor Subsystem	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 115	€ 180	€ 166	€ 133	€ 124
	6	0606	Mechanical Air Conditioning Compressor Subsystem	Electrical Air Conditioning Compressor Subsystem	Large SUV	VW Touareg	€ 132	€ 206	€ 190	€ 152	€ 142

D.2 Phase 2 Technologies Evaluated

A summary of the baseline and new technology configurations evaluated in the Phase 2, updated with the Eastern Europe labor rate assumption, is summarized below in **Table D-8**. The table, similar to the one found in Section C.2, has been modified with the new Cost Summary Table references.

Table D-8: Advance Powertrain Technologies, Evaluated in the Phase 2 Analysis, with Eastern Europe Labor Rate Assumption

Case Study ID	Baseline Technology Configuration	New Technology Configuration	Cost Summary Table
20**	Conventional Diesel Engine	Downsized Conventional Diesel Engine (e.g. I4-I3, I6-I4, V8-I6)	D-9
21**	Conventional Diesel Engine with 1800 Bar Fuel Injection Subsystem	Conventional Diesel Engine Upgraded with 2500 Bar Fuel Injection Subsystem	D-10
22**	Diesel Engine with Conventional Valvetrain Subsystem	Diesel Engine Upgraded with Discrete Variable Valve Timing and Lift (DVVT) Valvetrain subsystem	D-11
23**	Conventional Diesel Engine with a Cooled High Pressure Exhaust Gas Recirculation (EGR) Subsystem	Conventional Diesel Engine Upgraded with a High Pressure, Low Pressure Cooled High EGR Subsystem	D-12
31**	Conventional Gasoline Engine with a Uncooled Low Pressure EGR Subsystem	Conventional Gasoline Engine Upgraded with a Cooled Low Pressure EGR Subsystem	D-13
32**	Conventional Gasoline Engine with no EGR Subsystem	Conventional Gasoline Engine Upgraded with a Cooled Low Pressure EGR Subsystem	D-14
26**	6-Speed Manual Transmission	6-Speed Dry Dual Clutch Transmission (DCT)	D-15
30**	Conventional Powertrain Vehicle (Manual Transmission)	Conventional Powertrain Vehicle ((Manual Transmission) Upgraded with a Belt-Driven Starter Generator (BSG) Start-Stop System	D-16

Table D-9: Diesel Engine Downsizing Case Studies

*** Eastern Europe Labor Rate Substitution ***

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Diesel Engine Downsizing	2	2000B	Diesel I4 ICE Ave. Displacement = 1.2-1.4L Ave. Power = 62.5kW (85HP) Ave. Torque = 201N*m (148lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Downsized to Diesel I3 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Subcompact Passenger Vehicle	VW Polo	(€ 229)	(€ 174)	(€ 174)	(€ 185)	(€ 185)
	3	2001	Diesel I4 ICE Ave. Displacement = 1.6L Ave. Power = 78.6kW (107HP) Ave. Torque = 246N*m (181lb*ft) Typical Transmission Type: 5 or 6 speed MT or DCT Curb Weight: 1271kg (2803lb)	Downsized to Diesel I3 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Compact or Small Passenger Vehicle	VW Golf	(€ 234)	(€ 177)	(€ 177)	(€ 189)	(€ 189)
	4	2002	Diesel I4 ICE Ave. Displacement = 2.0L Ave. Power = 104kW (141HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1496kg (3299lb)	Downsized to Diesel I3 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Midsize Passenger Vehicle	VW Passat	(€ 245)	(€ 185)	(€ 185)	(€ 198)	(€ 198)
	5	2003A	Diesel I4 ICE Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Downsized to Diesel I3 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Midsize or Large Passenger Vehicle	VW Sharan	(€ 245)	(€ 185)	(€ 185)	(€ 198)	(€ 198)
	6	2003B	Diesel I6 ICE Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Downsized to Diesel I4 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Midsize or Large Passenger Vehicle	VW Sharan	(€ 354)	(€ 268)	(€ 268)	(€ 286)	(€ 286)
	7	2005	Diesel I4 ICE Ave. Displacement = 2.0-3.0L Ave. Power = 117.6W (160HP) Ave. Torque = 336N*m (248lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1590kg (3505lb)	Downsized to Diesel I3 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Small or Midsize SUV/COV or Mini Van	VW Tiguan	(€ 245)	(€ 185)	(€ 185)	(€ 198)	(€ 198)
	9	2006B	Diesel V8 ICE Ave. Displacement = 3.0 -4.2L Ave. Power = 213kW (290HP) Ave. Torque = 623N*m (460lb*ft) Typical Transmission Type: 8-Speed AT Curb Weight: 2207kg (4866lb)	Downsized to Diesel I6 ICE with same per Cylinder Displacement as Baseline Technology Configuration	Large SUV	VW Touareg	(€ 357)	(€ 271)	(€ 271)	(€ 288)	(€ 288)

Table D-10: 2500 Bar Diesel Fuel Injection System Case Study Results

*** Eastern Europe Labor Rate Substitution ***

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
High Pressure Fuel Injection, Diesel Engine	1	2100A	Diesel I3 ICE 1800 Bar Fuel Injection System Ave. Displacement = 1.0L Ave. Power = 62.5kW (85HP) Ave. Torque = 201N*m (148lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Diesel I3 ICE Upgraded to 2500 Bar Fuel Injection System	Subcompact Passenger Vehicle	VW Polo	€ 8	€ 11	€ 10	€ 9	€ 8
	2	2100B	Diesel I4 ICE 1800 Bar Fuel Injection System Ave. Displacement = 1.2-1.4L Ave. Power = 62.5kW (85HP) Ave. Torque = 201N*m (148lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Diesel I4 ICE Upgraded to 2500 Bar Fuel Injection System	Subcompact Passenger Vehicle	VW Polo	€ 11	€ 15	€ 14	€ 12	€ 11
	3	2101	Diesel I4 ICE 1800 Bar Fuel Injection System Ave. Displacement = 1.6L Ave. Power = 78.6kW (107HP) Ave. Torque = 246N*m (181lb*ft) Typical Transmission Type: 5 or 6 speed MT or DCT Curb Weight: 1271kg (2803lb)	Diesel I4 ICE Upgraded to 2500 Bar Fuel Injection System	Compact or Small Passenger Vehicle	VW Golf	€ 11	€ 15	€ 14	€ 12	€ 11
	4	2102	Diesel I4 ICE 1800 Bar Fuel Injection System Ave. Displacement = 2.0L Ave. Power = 104kW (141HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1496kg (3299lb)	Diesel I4 ICE Upgraded to 2500 Bar Fuel Injection System	Midsize Passenger Vehicle	VW Passat	€ 11	€ 15	€ 14	€ 12	€ 11
	6	2103B	Diesel I6 ICE 1800 Bar Fuel Injection System Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Diesel I6 ICE Upgraded to 2500 Bar Fuel Injection System	Midsize or Large Passenger Vehicle	VW Sharan	€ 16	€ 22	€ 20	€ 18	€ 16
	7	2105	Diesel I4 ICE 1800 Bar Fuel Injection System Ave. Displacement = 2.0-3.0L Ave. Power = 117.6W (160HP) Ave. Torque = 336N*m (248lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1590kg (3505lb)	Diesel I4 ICE Upgraded to 2500 Bar Fuel Injection System	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 11	€ 15	€ 14	€ 12	€ 11
	9	2106B	Diesel V8 ICE 1800 Bar Fuel Injection System Ave. Displacement = 3.0-4.2L Ave. Power = 213kW (290HP) Ave. Torque = 623N*m (460lb*ft) Typical Transmission Type: 8-Speed AT Curb Weight: 2207kg (4866lb)	Diesel V8 ICE Upgraded to 2500 Bar Fuel Injection System	Large SUV	VW Touareg	€ 21	€ 30	€ 27	€ 23	€ 22

**Table D-11: Discrete Variable Valve Lift and Timing Valvetrain (Diesel Engine)
Case Study Results**

*** Eastern Europe Labor Rate Substitution ***

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Variable Valve Timing and Lift	1	2200A	Diesel I3 ICE Conventional Valvetrain Ave. Displacement = 1.0L Ave. Power = 62.5kW (85HP) Ave. Torque = 201N*m (148lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Diesel I3 ICE Upgraded with Discrete Variable Valve Timing and Lift	Subcompact Passenger Vehicle	VW Polo	€ 72	€ 107	€ 98	€ 85	€ 79
	3	2201	Diesel I4 ICE Conventional Valvetrain Ave. Displacement = 1.6L Ave. Power = 78.6kW (107HP) Ave. Torque = 246N*m (181lb*ft) Typical Transmission Type: 5 or 6 speed MT or DCT Curb Weight: 1271kg (2803lb)	Diesel I4 ICE Upgraded with Discrete Variable Valve Timing and Lift	Compact or Small Passenger Vehicle	VW Golf	€ 78	€ 116	€ 105	€ 92	€ 85
	4	2202	Diesel I4 ICE Conventional Valvetrain Ave. Displacement = 2.0L Ave. Power = 104kW (141HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1496kg (3299lb)	Diesel I4 ICE Upgraded with Discrete Variable Valve Timing and Lift	Midsize Passenger Vehicle	VW Passat	€ 78	€ 116	€ 105	€ 92	€ 85
	5	2203A	Diesel I4 ICE Conventional Valvetrain Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Diesel I4 ICE Upgraded with Discrete Variable Valve Timing and Lift	Midsize or Large Passenger Vehicle	VW Sharan	€ 78	€ 116	€ 105	€ 92	€ 85
	6	2203B	Diesel I6 ICE Conventional Valvetrain Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Diesel I6 ICE Upgraded with Discrete Variable Valve Timing and Lift	Midsize or Large Passenger Vehicle	VW Sharan	€ 91	€ 135	€ 123	€ 107	€ 99
	7	2205	Diesel I4 ICE Conventional Valvetrain Ave. Displacement = 2.0-3.0L Ave. Power = 117.6W (160HP) Ave. Torque = 336N*m (248lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1590kg (3505lb)	Diesel I4 ICE Upgraded with Discrete Variable Valve Timing and Lift	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 78	€ 116	€ 105	€ 92	€ 85
	9	2206B	Diesel V8 ICE Conventional Valvetrain Ave. Displacement = 3.0-4.2L Ave. Power = 213kW (290HP) Ave. Torque = 623N*m (460lb*ft) Typical Transmission Type: 8-Speed AT Curb Weight: 2207kg (4866lb)	Diesel V8 ICE Upgraded with Discrete Variable Valve Timing and Lift	Large SUV	VW Touareg	€ 155	€ 231	€ 211	€ 184	€ 170

Table D-12: High Pressure, Low Pressure Cooled EGR (Diesel Engine) Case Study Results

*** Eastern Europe Labor Rate Substitution ***

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
High Pressure, Cooled Low Pressure EGR	1	2300A	Diesel I3 ICE Cooled High Pressure EGR Ave. Displacement = 1.0L Ave. Power = 62.5kW (85HP) Ave. Torque = 201N*m (148lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Diesel I3 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Subcompact Passenger Vehicle	VW Polo	€ 72	€ 99	€ 91	€ 79	€ 73
	3	2301	Diesel I4 ICE Cooled High Pressure EGR Ave. Displacement = 1.6L Ave. Power = 78.6kW (107HP) Ave. Torque = 246N*m (181lb*ft) Typical Transmission Type: 5 or 6 speed MT or DCT Curb Weight: 1271kg (2803lb)	Diesel I4 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Compact or Small Passenger Vehicle	VW Golf	€ 72	€ 99	€ 91	€ 79	€ 73
	4	2302	Diesel I4 ICE Cooled High Pressure EGR Ave. Displacement = 2.0L Ave. Power = 104kW (141HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1496kg (3299lb)	Diesel I4 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Midsize Passenger Vehicle	VW Passat	€ 72	€ 99	€ 91	€ 79	€ 73
	5	2303A	Diesel I4 ICE Cooled High Pressure EGR Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Diesel I4 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Midsize or Large Passenger Vehicle	VW Sharan	€ 72	€ 99	€ 91	€ 79	€ 73
	6	2303B	Diesel I6 ICE Cooled High Pressure EGR Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT or DCT, or 8-Speed AT Curb Weight: 1700kg (3749lb)	Diesel I6 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Midsize or Large Passenger Vehicle	VW Sharan	€ 72	€ 99	€ 91	€ 79	€ 73
	7	2305	Diesel I4 ICE Cooled High Pressure EGR Ave. Displacement = 2.0-3.0L Ave. Power = 117.6W (160HP) Ave. Torque = 336N*m (248lb*ft) Typical Transmission Type: 6-Speed MT or 8-Speed AT Curb Weight: 1590kg (3505lb)	Diesel I4 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 72	€ 99	€ 91	€ 79	€ 73
	9	2306B	Diesel V8 ICE Cooled High Pressure EGR Ave. Displacement = 3.0-4.2L Ave. Power = 213kW (290HP) Ave. Torque = 623N*m (460lb*ft) Typical Transmission Type: 8-Speed AT Curb Weight: 2207kg (4866lb)	Diesel V8 ICE Upgrade with High Pressure, Cooled Low Pressure EGR	Large SUV	VW Touareg	€ 72	€ 99	€ 91	€ 79	€ 73

Table D-13: Cooled Low Pressure EGR (Gasoline Engine) Case Study Results

*** Eastern Europe Labor Rate Substitution ***

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Gasoline, Cooled Low Pressure EGR (Compared to Uncooled Low Pressure EGR)	1	3100A	Gasoline I3 ICE Uncooled Low Pressure EGR Ave. Displacement = 1.2-1.4L Ave. Power = 74kW (100HP) Ave. Torque = 146N*m (108lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Gasoline I3 ICE Upgraded with Cooled Low Pressure EGR System	Subcompact Passenger Vehicle	VW Polo	€ 35	€ 48	€ 44	€ 42	€ 36
	3	3101	Gasoline I4 ICE Uncooled Low Pressure EGR Ave. Displacement = 1.4-1.6L Ave. Power = 89kW (121HP) Ave. Torque = 179N*m (132lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1271kg (2803lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Compact or Small Passenger Vehicle	VW Golf	€ 38	€ 52	€ 48	€ 45	€ 38
	4	3102	Gasoline I4 ICE Uncooled Low Pressure EGR Ave. Displacement = 1.6-2.0L Ave. Power = 115kW (157HP) Ave. Torque = 236N*m (174lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1496kg (3299lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Midsize Passenger Vehicle	VW Passat	€ 42	€ 59	€ 54	€ 51	€ 43
	5	3103A	Gasoline I4 ICE Uncooled Low Pressure EGR Ave. Displacement = 2.0-3.0L Ave. Power = 172kW (234HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Midsize or Large Passenger Vehicle	VW Sharan	€ 53	€ 73	€ 67	€ 63	€ 54
	6	3103B	Gasoline I6 ICE Uncooled Low Pressure EGR Ave. Displacement = 2.0-3.0L Ave. Power = 172kW (234HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Midsize or Large Passenger Vehicle	VW Sharan	€ 53	€ 73	€ 67	€ 63	€ 54
	7	3105	Gasoline I4 ICE Uncooled Low Pressure EGR Ave. Displacement = 1.2-3.0L Ave. Power = 131 kW (178HP) Ave. Torque = 264N*m (195lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1590kg (3505lb)	Gasoline I4 ICE Upgraded with Cooled Low Pressure EGR System	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 45	€ 63	€ 57	€ 54	€ 46
	9	3106B	Gasoline V8 ICE Uncooled Low Pressure EGR Ave. Displacement = 3.0-5.5 Ave. Power = 268 kW (364HP) Ave. Torque = 491N*m (362lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 2207kg (4867lb)	Gasoline V8 ICE Upgraded with Cooled Low Pressure EGR System	Large SUV	VW Touareg	€ 87	€ 97	€ 89	€ 84	€ 71

**Table D-14: Cooled Low Pressure EGR Compared to ICE with No EGR (Gasoline Engine)
Case Study Results**

*** Eastern Europe Labor Rate Substitution ***

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Gasoline, Cooled Low Pressure EGR (Compared to ICE with no EGR)	1	3200A	Gasoline I3 ICE No EGR Ave. Displacement = 1.2-1.4L Ave. Power = 74kW (100HP) Ave. Torque = 146N*m (108lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Gas I3 ICE Upgraded with Cooled Low Pressure EGR System	Subcompact Passenger Vehicle	VW Polo	€ 60	€ 83	€ 76	€ 71	€ 61
	3	3201	Gasoline I4 ICE No EGR Ave. Displacement = 1.4-1.6L Ave. Power = 89kW (121HP) Ave. Torque = 179N*m (132lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1271kg (2803lb)	Gas I4 ICE Upgraded with Cooled Low Pressure EGR System	Compact or Small Passenger Vehicle	VW Golf	€ 62	€ 87	€ 79	€ 75	€ 64
	4	3202	Gasoline I4 ICE No EGR Ave. Displacement = 1.6-2.0L Ave. Power = 115kW (157HP) Ave. Torque = 236N*m (174lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1496kg (3299lb)	Gas I4 ICE Upgraded with Cooled Low Pressure EGR System	Midsize Passenger Vehicle	VW Passat	€ 67	€ 93	€ 85	€ 80	€ 68
	5	3203A	Gasoline I4 ICE No EGR Ave. Displacement = 2.0-3.0L Ave. Power = 172kW (234HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Gas I4 ICE Upgraded with Cooled Low Pressure EGR System	Midsize or Large Passenger Vehicle	VW Sharan	€ 77	€ 107	€ 98	€ 93	€ 79
	6	3203B	Gasoline I6 ICE No EGR Ave. Displacement = 2.0-3.0L Ave. Power = 172kW (234HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Gas I6 ICE Upgraded with Cooled Low Pressure EGR System	Midsize or Large Passenger Vehicle	VW Sharan	€ 77	€ 107	€ 98	€ 93	€ 79
	7	3205	Gasoline I4 ICE No EGR Ave. Displacement = 1.2-3.0L Ave. Power = 131 kW (178HP) Ave. Torque = 264N*m (195lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1590kg (3505lb)	Gas I4 ICE Upgraded with Cooled Low Pressure EGR System	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 70	€ 97	€ 89	€ 84	€ 71
	9	3206B	Gasoline V8 ICE No EGR Ave. Displacement = 3.0-5.5 Ave. Power = 268 kW (364HP) Ave. Torque = 491N*m (362lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 2207kg (4867lb)	Gas V8 ICE Upgraded with Cooled Low Pressure EGR System	Large SUV	VW Touareg	€ 95	€ 131	€ 120	€ 113	€ 97

Table D-15: 6-Speed Dry Dual Clutch Transmission Case Study Results

*** Eastern Europe Labor Rate Substitution ***

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Dry Dual Clutch Transmission	1	2600A	Diesel I3 ICE Ave. Displacement = 1.0L Ave. Power = 62.5kW (85HP) Ave. Torque = 201N*m (148lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1084kg (2390lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Subcompact Passenger Vehicle	VW Polo	€ 233	€ 323	€ 295	€ 256	€ 237
	3	2601	Diesel I4 ICE Ave. Displacement = 1.6L Ave. Power = 78.6kW (107HP) Ave. Torque = 246N*m (181lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1271kg (2803lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Compact or Small Passenger Vehicle	VW Golf	€ 235	€ 327	€ 298	€ 259	€ 240
	4	2602	Diesel I4 ICE Ave. Displacement = 2.0L Ave. Power = 104kW (141HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1496kg (3299lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Midsize Passenger Vehicle	VW Passat	€ 240	€ 333	€ 304	€ 264	€ 245
	5	2603A	Diesel I4 ICE Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Midsize or Large Passenger Vehicle	VW Sharan	€ 246	€ 341	€ 311	€ 270	€ 250
	6	2603B	Diesel I6 ICE Ave. Displacement = 2.0L Ave. Power = 148.5W (202HP) Ave. Torque = 416N*m (306lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Midsize or Large Passenger Vehicle	VW Sharan	€ 246	€ 341	€ 311	€ 270	€ 250
	7	2605	Diesel I4 ICE Ave. Displacement = 2.0-3.0L Ave. Power = 117.6W (160HP) Ave. Torque = 336N*m (248lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1590kg (3505lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 241	€ 334	€ 305	€ 265	€ 246
	9	2606B	Diesel V8 ICE Ave. Displacement = 3.0 -4.2L Ave. Power = 213kW (290HP) Ave. Torque = 623N*m (460lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 2207kg (4866lb)	Upgrade with 6-Speed Dry Dual Clutch Transmission	Large SUV	VW Touareg	€ 258	€ 358	€ 327	€ 284	€ 263

Table D-16: Belt-Driven, Starter-Generator (BSG) Start-Stop Hybrid Electric
***** Eastern Europe Labor Rate Substitution *****

Technology	ID	Case Study #	Baseline Technology Configuration	New Technology Configuration	European Market Segment	European Vehicle Segment Example	Net Incremental Direct Manufacturing Cost (NIDMC)	Net Incremental Technology Cost (NITC)			
								2012	2016	2020	2025
Start-Stop Hybrid Electric Vehicle Technology	2	3000B	Gasoline I4 ICE Conventional Powertrain Ave. Displacement = 1.2-1.4L Ave. Power = 74kW (100HP) Ave. Torque = 146N*m (108lb*ft) Typical Transmission Type: 5-Speed MT Curb Weight: 1084kg (2390lb)	Gasoline I4 ICE, Manual Transmission, upgraded with Belt-Driven, Starter-Generator (BSG) System.	Subcompact Passenger Vehicle	VW Polo	€ 241	€ 476	€ 334	€ 282	€ 251
	3	3001	Gasoline I4 ICE Conventional Powertrain Ave. Displacement = 1.4-1.6L Ave. Power = 89kW (121HP) Ave. Torque = 179N*m (132lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1271kg (2803lb)	Gasoline I4 ICE, Manual Transmission, Upgraded with Belt-Driven, Starter-Generator (BSG) System.	Compact or Small Passenger Vehicle	VW Golf	€ 251	€ 496	€ 348	€ 294	€ 262
	4	3002	Gasoline I4 ICE Conventional Powertrain Ave. Displacement = 1.6-2.0L Ave. Power = 115kW (157HP) Ave. Torque = 236N*m (174lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1496kg (3299lb)	Gasoline I4 ICE, Manual Transmission, Upgraded with Belt-Driven, Starter-Generator (BSG) System.	Midsize Passenger Vehicle	VW Passat	€ 266	€ 525	€ 369	€ 312	€ 277
	6	3003B	Gasoline I6 ICE Conventional Powertrain Ave. Displacement = 2.0-3.0L Ave. Power = 172kW (234HP) Ave. Torque = 321N*m (237lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1700kg (3749lb)	Gasoline I6 ICE, Manual Transmission, Upgraded with Belt-Driven, Starter-Generator (BSG) System.	Midsize or Large Passenger Vehicle	VW Sharan	€ 284	€ 561	€ 394	€ 333	€ 296
	7	3005	Gasoline I4 ICE Conventional Powertrain Ave. Displacement = 1.2-3.0L Ave. Power = 131 kW (178HP) Ave. Torque = 264N*m (195lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 1590kg (3505lb)	Gasoline I4 ICE, Manual Transmission, Upgraded with Belt-Driven, Starter-Generator (BSG) System.	Small or Midsize SUV/COV or Mini Van	VW Tiguan	€ 273	€ 538	€ 378	€ 319	€ 284
	9	3006B	Gasoline V8 ICE Conventional Powertrain Ave. Displacement = 3.0-5.5 Ave. Power = 268 kW (364HP) Ave. Torque = 491N*m (362lb*ft) Typical Transmission Type: 6-Speed MT Curb Weight: 2207kg (4867lb)	Gasoline V8 ICE, Manual Transmission, Upgraded with Belt-Driven, Starter-Generator (BSG) System.	Large SUV	VW Touareg	€ 363	€ 717	€ 504	€ 425	€ 379

D.3 Eastern Europe Labor Rate Sensitivity Analysis Comparison

In summary, a 77% percent labor rate reduction in the Phase 1 and Phase 2 analyses resulted in a Net Incremental Technology Cost change for most studies in the 15-20% range. The average difference for each technology configuration evaluated in the Phase 1 and Phase 2 analysis, is shown below in **Table D-17** and **Table D-18** respectively. The percent difference for each technology configuration is directly related to the labor contribution in the total manufacturing cost (i.e., total manufacturing cost = material + labor + manufacturing overhead) and associated mark-ups, a factor of the total manufacturing cost. For technologies where labor contribution was low comparatively to the material contribution, the effect of the lower labor rate was minimal. For example in the mechanical versus electrical air conditioning compressor analysis, the cost of the more traditional compressor components (e.g. housings, shafts, fasteners, seals, etc.) were cost neutral in comparison. The added incremental costs were largely associated with low and high voltage electronic components and assemblies with significant material costs. In the cost models, material costs include raw materials and commodity purchased component costs (e.g. circuit boards, passive electronic components, active electronics components).

Table D-17: Average Percent Reduction in Net Incremental Technology Costs with Average Labor Rate reduced by 77%, Phase 1 Technology Configurations

Case Study ID	Baseline Technology Configuration	New Technology Configuration	Average NITC Reduction Assuming Average Eastern European Labor Rate	Average Percent NITC Reduction Assuming Average Eastern European Labor Rate
01**	Naturally Aspirated (NA), Port Fuel Injected (PFI), Gasoline Internal Combustion Engine (ICE)	Downsized (DS), Turbocharged (Turbo), Direct Injection (DI) Gasoline Internal Combustion Engine (ICE)	€ 97	21.3%
02**	Dual Overhead Cam (DOHC), NA, PFI, Dual-Variable Valve Timing (D-VVT), Gasoline ICE	Single Overhead Cam (SOHC), NA, PFI, Multi-Air Variable Valve Timing and Lift (VVTL), Gasoline ICE	€ 26	18.8%
08**	5-Speed Automatic Transmission	6-Speed Automatic Transmission	-€ 12	-19.5%
10**	6-Speed Automatic Transmission	8-Speed Automatic Transmission	€ 10	17.7%
09**	6-Speed Automatic Transmission	6-Speed Dual Clutch Transmission	-€ 15	-27.3%
04**	Conventional Powertrain Vehicle	Conventional Powertrain Vehicle Upgraded with a Belt Alternator Starter (BAS) Start-Stop System	€ 314	19.1%
05**	Conventional Powertrain Vehicle	Power-Split Hybrid Electric Vehicle	€ 579	15.2%
07**	Conventional Powertrain Vehicle	P2 Hybrid Electric Vehicle	€ 594	15.5%
06**	Mechanical Air Conditioning Compressor System	Electrical Air Conditioning Compressor System	€ 4	2.3%

Notes: ¹ Negative percentage indicates reduced savings as the base technology is less expensive to manufacture in the low cost country (i.e., Eastern Europe)

Table D-18: Average Percent Reduction in Net Incremental Technology Costs with Average Labor Rate reduced by 77%, Phase 2 Technology Configurations

Case Study ID	Baseline Technology Configuration	New Technology Configuration	Average NITC Reduction Assuming Average Eastern European Labor Rate	Average Percent NITC Reduction Assuming Average Eastern European Labor Rate
20**	Conventional Diesel Engine	Downsized Conventional Diesel Engine (e.g. I4-I3, I6-I4, V8-I6)	-€ 51	-19.2%
21**	Conventional Diesel Engine with 1800 Bar Fuel Injection Subsystem	Conventional Diesel Engine Upgraded with 2500 Bar Fuel Injection Subsystem	€ 1	5.3%
22**	Diesel Engine with Conventional Valvetrain Subsystem	Diesel Engine Upgraded with Discrete Variable Valve Timing and Lift (VVTL) Valvetrain subsystem	€ 27	19.1%
23**	Conventional Diesel Engine with a Cooled High Pressure Exhaust Gas Recirculation (EGR) Subsystem	Conventional Diesel Engine Upgraded with a High Pressure, Low Pressure Cooled High EGR Subsystem	€ 20	18.9%
31**	Conventional Gasoline Engine with a Uncooled Low Pressure EGR Subsystem	Conventional Gasoline Engine Upgraded with a Cooled Low Pressure EGR Subsystem	€ 14	19.1%
32**	Conventional Gasoline Engine with no EGR Subsystem	Conventional Gasoline Engine Upgraded with a Cooled Low Pressure EGR Subsystem	€ 21	19.1%
26**	6-Speed Manual Transmission	6-Speed Dry Dual Clutch Transmission (DCT)	€ 68	19.1%
30**	Conventional Powertrain Vehicle (Manual Transmission)	Conventional Powertrain Vehicle ((Manual Transmission) Upgraded with a Belt-Driven Starter Generator (BSG) Start-Stop System	€ 93	19.2%

Notes: ¹ Negative percentage indicates reduced savings as the base technology is less expensive to manufacture in the low cost country (i.e., Eastern Europe)

As stated in Section B.2, a cleansheet cost modeling approach would be required to assess the actual impact of manufacturing selected components in low cost Eastern Europe countries versus Western industrialized nations. Though the values above represent a rough order of magnitude of the potential cost differences which may be applicable if the components are suitable for manufacturing in low cost countries.

E. Conclusion

This report provides a summary of the results completed in the Phase 1 and Phase 2 Light-Duty Vehicle Technology Cost assessments. For additional details on each of the case studies evaluated, please reference the respective Phase 1 or Phase 2 reports.^{6,7}

The labor sensitivity analysis provides a good “what if” type analysis on potential Net Incremental Technology Costs (NITC) if all hardware was manufactured with a labor rate reduced by 77%; representing an average Eastern European labor rate. Based on industry expectations that selected products can be manufactured at cost reductions in the order of 30%, the numbers calculated within this analysis are directionally correct, though not founded on a set of actual boundary conditions.

⁶ FEV, “Light-Duty Vehicle Technology Cost Analysis – European Vehicle Market (Phase 1),” prepared for the International Council on Clean Transportation (ICCT), Revised Report 08/07/2013 (Original May 17, 2012)

⁷ FEV, “Light-Duty Vehicle Technology Cost Analysis – European Vehicle Market, Additional Case Studies (Phase 2),” prepared for the International Council on Clean Transportation (ICCT), September 27, 2012

F. Abbreviation and Acronyms

AT	Automatic Transmission
BAS	Belt Alternator Starter
BSG	Belt-Driven Starter Generator
COV	Crossover Vehicle
DI	Direct Injection
DCT	Dual Clutch Transmission (aka DSG)
DOHC	Dual Overhead Cams
DS	Down Sized
DSG	Dual Shit Gearbox (aka DCT)
DVVT	Dual Variable Valve Timing
ED&T	Engineering, Design, and Testing
EGR	Exhaust Gas Recirculation
GDI	Gasoline Direct Injection
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
ICCT	International Council on Clean Transportation
ICM	Indirect Cost Multiplier
MT	Manual Transmission
NA	Naturally Aspirated
NIDMC	Net Incremental Direct Manufacturing Cost
NITC	Net Incremental Technology Cost
PFI	Port Fuel Injected
SG&A	Selling, General and Administrative
SHOC	Single Overhead Cam
SUV	Sport Utility Vehicle
US-EPA	United States Environmental Protection Agency
VVT	Variable Valve Timing
VVTL	Variable Valve Timing and Lift
VW	Volkswagen