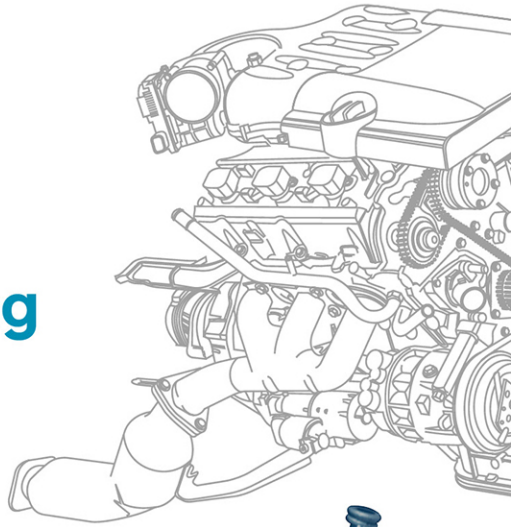
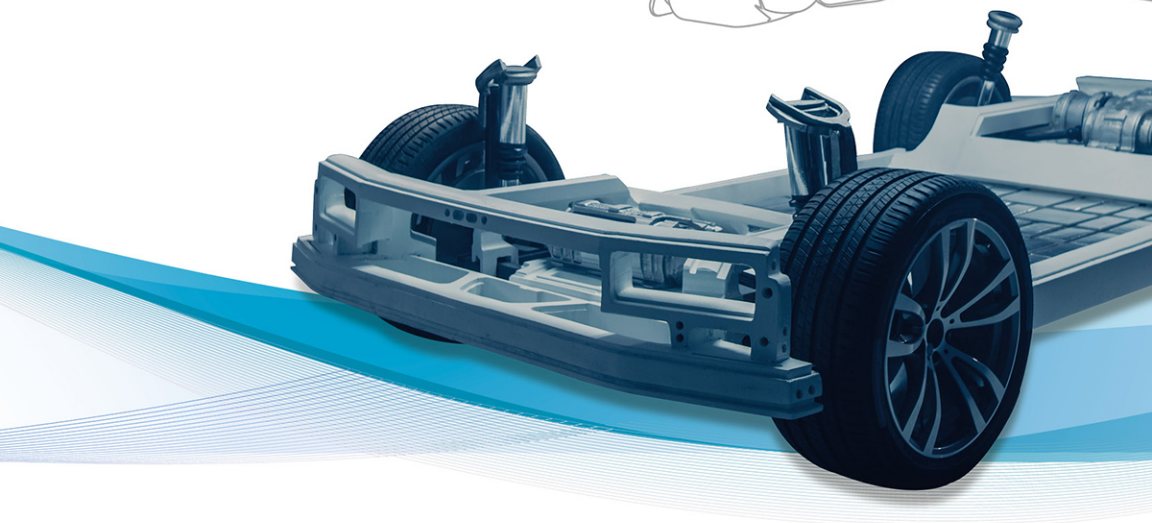
www.tenergy-x.com

Total solution provider for vehicle engineering





TENERGY

World Best with The Best
Driving the future through leading technology

Contents

TENERGY is trying to lead green technology and listen to the voice of clients.

TENERGY is an engineering service provider of automotive industry with utmost professionalism and agility.

We have our special expertise and best technology to make success for our clients.

We offer detail and flexible solutions for powertrain and vehicle development as total programs or selected services.

Strong partnership and engineering perfection are our commitments.

TENERGY is a technical leader in the field of energy conversion and environmental technology.

TENERGY is ready to support the clients who are thirsty for higher level of engineering to make the green world.

Tenergy Engineering Center

in Pangyo 2nd Techno Valley (to be completed in Jan., 2025)

Under construction

Dongtan R&D Center

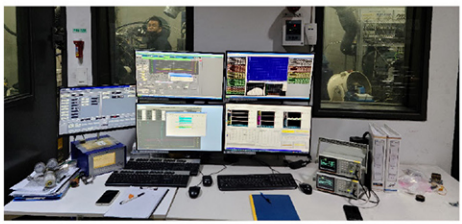
Emission Test Center

Dongtan R&D Center

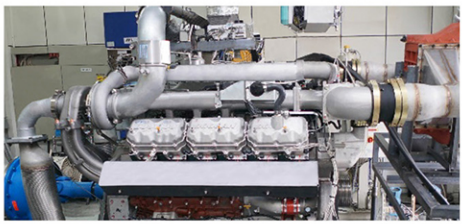
Engine & Transmission dynamometers

Test cell	Dynamometer			Gas analyzer model
	Type	kW	Maker	
T-01	AC	390	Schorch	
T-02	AC	390	Schorch	
T-03	AC	390	Schorch	Horiba 9100DEGR
T-04	**E-dyno(AC)**	**390**	**Schorch**	**Bat. Sim. 360kW / 1000V / 800A**
T-05	AC	220	AVL	Horiba 9100DEGR
T-06	AC	390	AVL	Horiba 7000
T-07	AC	390	Schorch	
T-08	AC	350	Schorch	Horiba 9100DEGR
T-09	AC	390	Schorch	Horiba 7000
T-10	Hydraulic	2,100	Schenck	Horiba 9100DEGR
T-11	**E-PT(AC*2EA)**	**700**	**AVL**	**Bat. Sim. 360kW / 1000V / 800A**

Engine & EV-motor test room



Hydraulic dynamometer for Industrial engine test



E-PT

Bat. Simulator(E-dyno)

Benchmarking room

Chassis dynamometers

Type	Front(kW)	Rear(kW)	Emission analyzer
4WD HORIBA	150	150	HORIBA MEXA-ONE • 3ch analyzer, FTIR • Direct sampling • Europe 14 ATCT and 25 emission/CO2

Emission analyzer

Soaking room

Cold chamber

Energy and Environment with a Passion for Green

WORLD BEST WITH THE BEST

Driving the future through leading technology

TENERGY is dedicated to providing clients with an extensive portfolio of leading technology and superior consulting services as well as next generation solutions.

Our design concept is based on achieving what clients want: high power, fuel economy, low cost, compact design and environmentally friendly one. All of the achieved design outputs are validated through innovative and advanced technology method at engine test cells and various rigs under controlled conditions during the development process.

TENERGY provides not only engine development services but also complete power train calibration ones to clients.

Our calibration engineers have vast experiences in engine and transmission applications. In addition, they are familiar with many types of engine management systems from various EMS suppliers. We have the strong belief that TENERGY can make a great breakthrough from the old routine in energy saving and environment protection technology of future engines.

Current demands to save the planet via engine technology through more economical and cleaner engines are growing all over the world every year. TENERGY is ready to support to develop next generation, environmentally friendly Gasoline and Diesel engines. The aim is now to reduce the fuel consumption of engines through innovations, including downsizing, direct injection, variable valve train and new diesel FIE system.

Achievements

EV / FCEV conversion

Proto Vehicle Development
- Design engineering
- Powertrain system integration
- Controller development
- Vehicle test and calibration

xEV test of analysis

Electric Vehicle

Hyundai (IONIQ 5 AWD)
- Thermal management system
- Battery system
- Motor inverter system
  (800V charge system, DAS system)

KIA (EV6 RWD)
- Thermal management system
- Battery system
- Motor inverter system

Hyundai (Kona Electric, 20MY)
- Thermal management system
- Battery system
- Motor inverter system

Hyundai (IONIQ 6, RWD)
- Thermal management system
- Battery system
- Motor inverter system

Tesla (Model 3, LFP)
- Thermal management system
- Battery system
  (LFP CATL cell)
- Motor inverter system

KIA (EV6 GT)
- Thermal management system
- Battery system
- Motor inverter system
  (Dual inverter system)

KIA (EV9)
- Thermal management system
  (3 seat HVAC system)
- Battery system
- Motor inverter system

Hyundai (Kona Electric, 23MY)
- Thermal management system
- Battery system
- Motor inverter system

Tesla (Model 3, PTC)
- Thermal management system
  (Super bottle valve)
- Battery system
- Motor inverter system

Tesla (Model Y, Heat pump)
- Thermal management system
  (Octo valve)
- Battery system
- Motor inverter system

Chevrolet (Bolt)
- Thermal management system
- Battery system
- Motor inverter system

Audi (e-tron 55 quattro)
- Thermal management system
- Battery system
- Motor inverter system

Nissan (Ariya, FWD)
- Thermal management system
- Battery system
- Motor inverter system
  (WRSM motor)

Changan (SL03)
- Thermal management system
- Battery system
  (High frequency AC heating)
- Motor inverter system

XiaoPeng (P7 4WD)
- Thermal management system
- Battery system
- Motor inverter system
- ADAS

Fuel cell vehicle

Hyundai (NEXO FCEV)
- Thermal management system
- Fuel cell system
- Battery system
- Motor inverter system

BMW (i3)
- Thermal management system
- Battery system
  (Battery refrigerant cooling)
- Motor inverter system

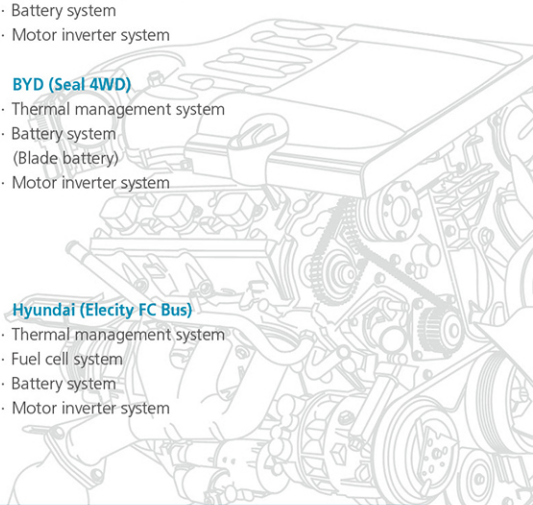
Volkswagen (ID.4, Pro)
- Thermal management system
  (CO2 refrigerant)
- Battery system
- Motor inverter system

BYD (Tang EV 600d)
- Thermal management system
- Battery system
- Motor inverter system
  (180kW 2EA)

BYD (Song EV pro)
- Thermal management system
- Battery system
- Motor inverter system

BYD (Seal 4WD)
- Thermal management system
- Battery system
  (Blade battery)
- Motor inverter system

Hyundai (Elecity FC Bus)
- Thermal management system
- Fuel cell system
- Battery system
- Motor inverter system



Achievements

Vehicle engineering

Gazelle Next
Single Cabin

- Press die
- Body assembly
- Injection mold

Gazelle Next
Double Cabin

- Press die
- Body assembly
- Injection mold

Gazelle Next
Van / Bus / Long

- Press die
- Body assembly
- Axle & Gear box assembly line

Gazelle NN
(Facelift)

- Press die
- Hood hemming
- Injection mold

GAZon Truck

- Press die
- Body assembly

Gazelle City

- Body frame assembly

Sobol NN

- Press die
- Laser trimming
- Body assembly
- Hemming

LADA Vesta Wagon & Cross

- Body / In-exterior design
- Press die
- Injection mold

LADA Vesta Facelift

- Press die

LADA NIVA Legend

- Press die
- Injection mold

LADA Largus

- Press die

New Saga
- Design engineering
- Press die
- Body assembly
- General assembly

Exora
- Design engineering
- Press die
- Body assembly
- General assembly

Preve
- Press die
- Body assembly
- General assembly

Iriz
- Design engineering
- Press die
- Body assembly
- General assembly

Persona-R
- Design engineering
- Press die
- Body assembly
- General assembly

Saga-R
- Design engineering
- Press die
- Body assembly
- General assembly

Hexa
- Design engineering
- Press die
- Body assembly
- Injection mold

Nano Pelican
- Injection mold

CR-V

Civic

Jazz

- KD Body assembly line (Malaysia)

Essentia

Aveo

Sail

D-MAX

- KD Body assembly line (South America)

Achievements

Engine development

A2300T IDI engine
- Cylinder head design
- Mechanical development
- Vehicle cooling system development

2400T DI engine
- Design, CAE
- Test & development, SOP support

D3400T DI engine
- Design, CAE
- Test & development, SOP support

2.4L (TCI, TC, NA) CRDi Tier 4 engine
- Combustion development
- Mechanical & durability development
- Engine & DPF calibration

2.0 / 2.4L Euro 5 Gasoline engine
- Design (Concept, definitive & detail design)
- Combustion development
- Mechanical & durability development

1.8 / 2.4L(TC, NA) CRDi Tier 4 engine
- Combustion development
- Mechanical & durability development
- Engine & DPF calibration

3.4L TCI CRDi Tier 4 engine
- Mechanical development
- Durability development

1.2L NA Gasoline Euro 5 engine
- Design, CAE
- Combustion development
- Functional development

1.3L NA Gasoline Euro 4 engine
- Design, CAE
- Combustion development
- Mechanical & durability development

1.9 / 2.5L TCI CRDi Tier 4 engine
- Combustion development
- Mechanical & durability development
- Vehicle calibration with CDPF

27L(V-12) TCI CRDi Diesel engine
- Optimization of crank-train system
- Improvement of bearing reliability

30L(V-12) TCI CRDi Diesel engine
- Concept, definitive & detail design for 1MW power plant
- PFP 220 bar

1.8L Turbo-charged Gasoline Euro 5 engine
- Design, CAE
- Combustion development
- Mechanical & durability development
- Engine & vehicle calibration

Denso Piezo 2,000 & 2,200bar FIE application to HMC R-engine
- R-Engine base definition
- Denso FIE packaging to R-Engine
- Engine calibration & feasibility test

6.6L Dual fuel engine (LPG & Diesel)
- System layout design including EMS system
- Combustion development

0.033L Gasoline engine
- Design (Concept, definitive & detail design)
- CAE
- Test & development

2.0L GDI engine
- Design (Concept, definitive & detail design)
- Combustion development

2.0L T-GDI engine
- 10% performance improvement
- Vehicle calibration ULEV 2 (EURO 5 equivalent)

2.0L T-GDI engine
- Design, CAE
- Combustion development
- Engine calibration

2.7L NA Gasoline Euro 5 engine
- Design, CAE
- Combustion development
- Mechanical & durability development
- Engine calibration

125 / 150cc single cylinder engine
- Design, CAE
- Combustion development
- Mechanical & durability development
- Engine calibration

149cc single cylinder engine for CHP
- Design, CAE
- Combustion development
- Mechanical & durability development

1.5L NA Gasoline Euro 5 engine
- Design, CAE
- Combustion development
- Mechanical & durability development

22L(V-12) TCI CRDi Diesel engine
- Design, CAE
- Combustion development
- Mechanical & durability development
- Engine calibration

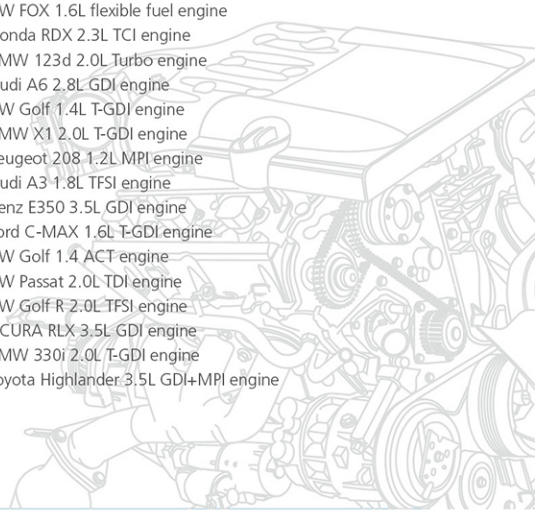
2.4L NA Gasoline Euro 5 engine
- Design, CAE
- Combustion development
- Mechanical & durability development
- Engine & vehicle calibration

TENERGY 1.2 / 1.6L T-GDI engine
- I-3 & I-4 NA & T-GDI family engine
- Design, CAE
- Combustion development

177cc 2-Cycle engine
- Design & CAE
- Combustion development
- Mechanical & durability development

330cc Wankel Rotary engine
- Design & CAE
- Combustion development
- Mechanical & durability development

Engine benchmarking test
- VW FOX 1.6L flexible fuel engine
- Honda RDX 2.3L TCI engine
- BMW 123d 2.0L Turbo engine
- Audi A6 2.8L GDI engine
- VW Golf 1.4L T-GDI engine
- BMW X1 2.0L T-GDI engine
- Peugeot 208 1.2L MPI engine
- Audi A3 1.8L TFSI engine
- Benz E350 3.5L GDI engine
- Ford C-MAX 1.6L T-GDI engine
- VW Golf 1.4 ACT engine
- VW Passat 2.0L TDI engine
- VW Golf R 2.0L TFSI engine
- ACURA RLX 3.5L GDI engine
- BMW 330i 2.0L T-GDI engine
- Toyota Highlander 3.5L GDI+MPI engine



Achievements

EMS calibration

Diesel vehicle calibration

A150 2.0 CRDi calibration
- EURO 5/4 regulation
- Emission/EOBD/CDPF/Drivability calibration

C150 2.0 CRDi calibration
- EURO 5/4 regulation
- Emission/ EOBD/CDPF/Drivability calibration

C211 2.0 CRDi calibration
- EURO 5/4 regulation
- Emission/EOBD/CDPF/Drivability calibration

Y295 2.2 CRDi calibration
- EURO 6b regulation
- Emission/EOBD/CDPF/LNT/Drivability calibration
- RDE monitoring

Y400 2.2 CRDi calibration
- EURO 6b/5/4 regulation
- Emission/EOBD/CDPF/LNT/Drivability calibration
- RDE monitoring

Q200/201 2.2 CRDi calibration
- EURO 6b/4 regulation
- Emission/EOBD/CDPF/Drivability calibration
- RDE monitoring

Gasoline vehicle calibration

C300/X150 1.5 T-GDI calibration
- K-SULEV30 regulation
- Emission/KOBD/Drivability calibration

X150 1.5 T-GDI calibration
- EURO 6d temp regulation
- Emission/EOBD/Drivability calibration
- GPF/RDE calibration

C300 2.0 MPI calibration
- EURO 6b regulation
- Emission/EOBD/Drivability calibration

J115/C330/X180 1.5 T-GDI calibration
- EU6e/SULEV30 regulation
- Emission/OBD/Drivability calibration

1.8 T-GDI calibration
- EURO 5 regulation
- Emission/EOBD/Drivability calibration

3.3L MPI calibration
- OBD2 calibration

11L CNG calibration
- EURO 6b regulation
- CNG lean-burn engine OBD logic/calibration

125cc/250cc Gasoline(single cylinder)
- Emission/OBD/Drivability calibration

Transmission development

T-MAT development
- Torque interruption free (Manual-based Automatic Transmission)
- Concept & layout design
- Tests & calibration

Manual transmission
- Design, CAE
- Longitudinal 5 speed M/T
- Shift control layout design

4WD Transfer case
- Full-time transfer case with high gear and low gear
- Concept & layout design
- Test & development

EV A/T development (w/o Torque converter)
- Turn-key project for Electric vehicle
- Concept & Layout design, Test & Development, SOP support
- All Control Logic development & Verification

A/T calibration
- Calibrating shifting-process control and specific operating modes
- Designing shift points

Fan clutch development
- CVT type using oil pump
- Electronically controlled
- Fail-safe design

Reduction gear assembly
- Design for helicopter drone
- With spur gear & spiral bevel gear
- Assembling and dynamo test

HDT(Hydro-Dynamic Transmission) w/Torque converter
- Turn-key project
- Concept & detail design, CAE, Test & development
- TCU S/W development & Calibration

Energy Flow-Down Method

Great success for development of better FE

7~15% improvement of FTP-75/NEDC mode F/E

Company	Vehicle program
H	Passenger car (1.1ℓ/1.5ℓ/1.6ℓ/2.0ℓ/2.4ℓ/3.3ℓ/3.8ℓ)
	Diesel SUV (2.0ℓ, 2.2ℓ)
	Commercial vehicle (24 ton truck)
G	Diesel SUV for Korean/US/EU market (2.0ℓ)
S	Diesel SUV & Van (2.5/2.7ℓ)
	Diesel SUV 2.0ℓ
R	Passenger car (V6 3.5ℓ)
TOYOTA, HONDA, RENAULT, VOLVO, AUDI, etc.	More than 25 benchmarking analyses

Summary of Major Achievements

Business area			No. of projects
xEV development	Vehicle test of analysis	EV	17
		FCEV	2
		HEV	6
	Vehicle conversion	EV	3
		FCEV	3
		HEV	1
	xEV System benchmarking test		6
	Research analysis (E/E, Architecture, SDV, etc.)		5
	xEV Vehicle controller development (VCU, HMU, etc.)		16
	Performance & Efficiency evaluation (E-Dyno.)		7
	Efficiency & Durability test (E-PT Dyno.)		4
	EV Rotor core reliability (E-Dyno.)		8
Vehicle engineering	Design engineering	Vehicle design	5
		EV Conversion design	4
		System design	12
		Prototype	10
	Manufacturing engineering	Press die development	27
		Body assembly development	23
		General assembly development	8
		Paint shop development	1
		Injection mold development	14

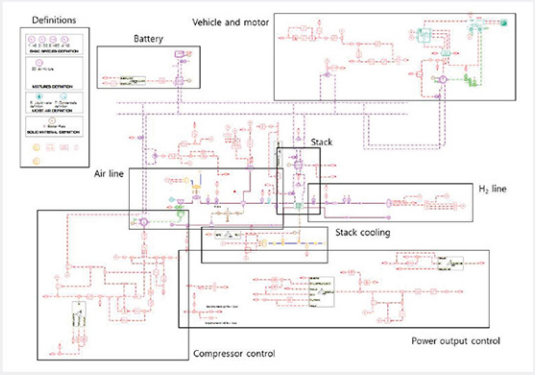
As of April 2024, for the past 15 years

Business area			No. of projects
Engine development	Turn-key project (New development)		10
	Improvement		19
	Benchmarking (Test & Design)		34
	Test development		8
Transmission development	Turn-key project (New development)		9
	Improvement (M/T, A/T, T/case, etc.)		7
	Benchmarking (Design)		14
	TCU calibration		6
EMS calibration - Gasoline, Diesel, LPG, Hybrid - EMS: Bosch, Vitesco, Delphi, HNB	Turn-key project	Europe (EU6e, EUS, etc.)	23
		Korea (SULEV, ULEV, etc.)	15
	Emission & OBD	Europe/India (EU6, BS6, etc.)	109
		Korea/USA (SULEV, ULEV,etc.)	11
	Drivability	Europe/India (EU6, BS6, etc.)	13
		Korea/USA (SULEV, ULEV, etc.)	4
EMS validation		Europe/India (EU6, BS6, etc.)	12
		Korea/USA (SULEV, ULEV, etc.)	7
PVE (Production vehicle evaluation)		USA (SULEV, ULEV, TIER-3, etc.)	18

As of April 2024, for the past 15 years

xEV Vehicle develop.

Concept design using vehicle system simulation : BEV / FCEV / Hybrid ICE



Work flow of development

1 Packaging Design

- FC / PE system
- FC / PE cooling system
- H2 supply system
- Wire harness
- HVCU
- Energy flow display

2 System Evaluation

- FC system
  - Performance
  - Efficiency
- HVCU control unit inspection test
- Battery / PE system

3 Proto Vehicle Development

- Repainting
- Disassembly
- Components installation
- Filling hydrogen

4 Proto Vehicle Test

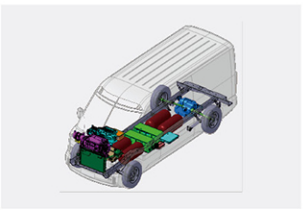
- Calibration
  - Driving control
  - Power control
- Test
  - Fuel economy test
  - Drivability test

FCEV develop.

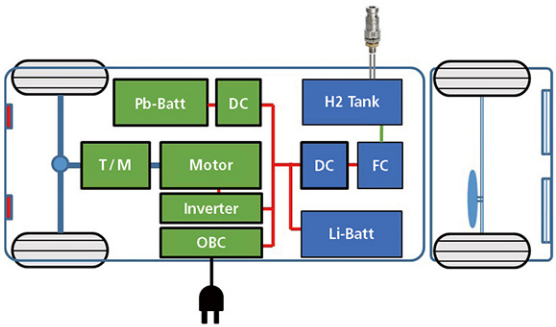
Tenergy solution : COC (Constant Output Control) fuel cell hybrid system
High vehicle system efficiency, Low FC degradation.

FC Mini Bus

FC LCV



FC Long Size Bus



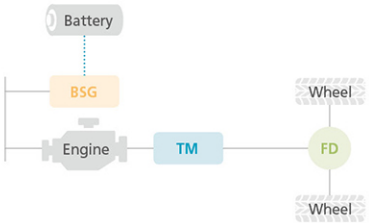
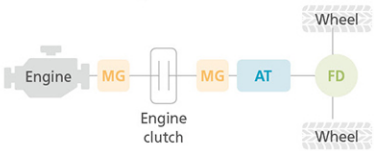
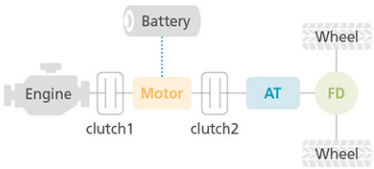
	Hyundai [Nexo]	TOYOTA [SORA]	TENERGY (COC FC system)	Remark
Motor	120kW	226kW	100kW	-
Battery	1.6kWh	7.5kWh	24 kWh	QC, OBC charge
FC system	95kW	228kW	30kW	High effi. const. output
H2 tank	157L	600L	153L (6.0kg)	700bar, Type 4
HEV type	Full FC type		COC type	-
Pros.	Low weight		High effi., FC low degradation	-
Cons.	Low effi., FC degradation		High weight	-

HEV develop.

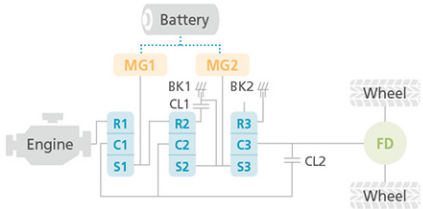
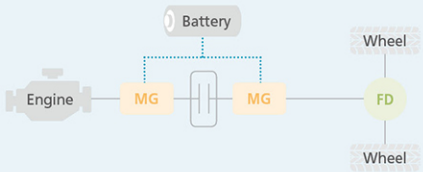
Tenergy solution : Series and parallel multi mode system.

▶ Simple structure, High performance

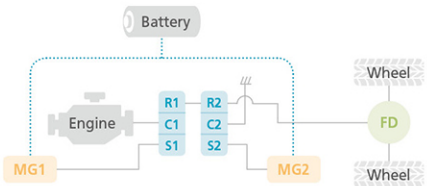
Parallel

	Architecture	OEM	
P0 / P1			• Limited functionality of EV driving and regeneration
P2	**2 motor 1clutch system**  **1 motor 2clutch system** 		• Engine drag can be eliminated during EV driving to increase system efficiency • Limited PHEV functionality • 2 motor 1 clutch system is easier to turn engine on than 1 motor 2 clutch system

Multi Mode

	Architecture	OEM	
Power-split / Parallel / Series	Tahoe / Yukon 	GM, CHRYSLER, Mercedes-Benz	• System efficiency depends on the configuration of gear and motor set
Series+ Parallel		HONDA, BYD, TENERGY	• Tenergy solution • Simple structure with high performance

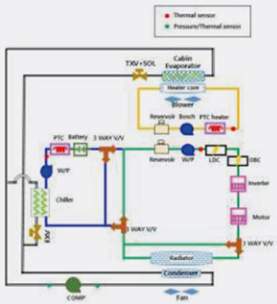
Power-split

Architecture	OEM	
	TOYOTA, Ford, NISSAN, LEXUS EXPERIENCE AMAZING	• Simple and easy to control

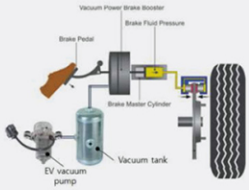
EV develop.

Tenergy solution : EV Conversion from ICE vehicle
Development of EV systems (TMS, ePT, Monitor, Controller, etc.)

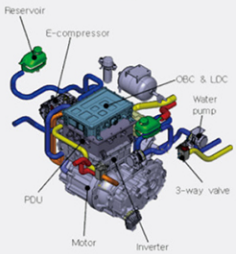
Thermal management system



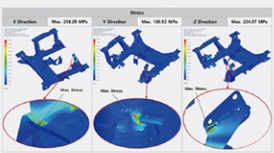
Brake system



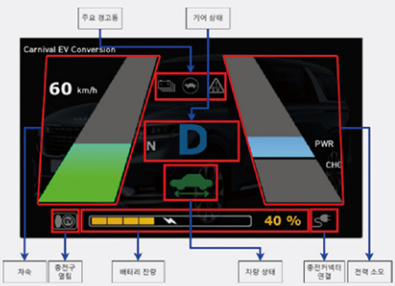
ePT system



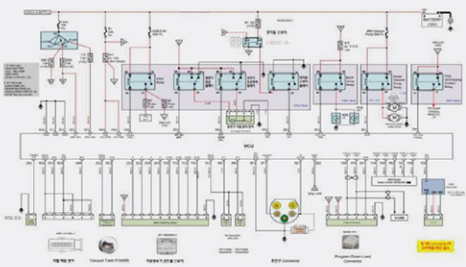
CAE analysis



EV system monitor



Controller diagram



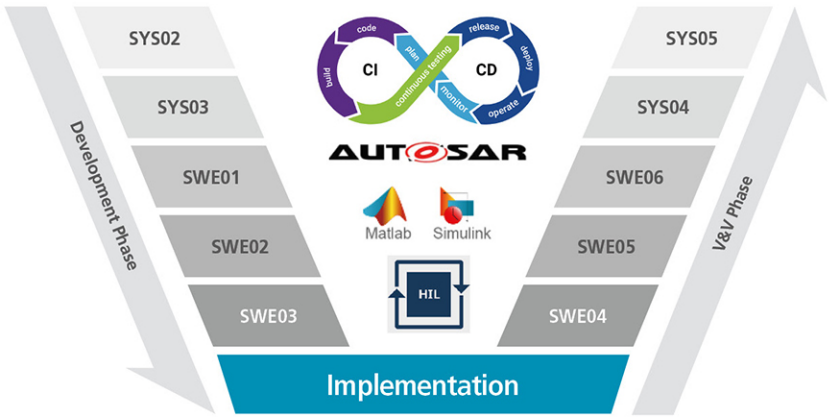
Controller develop.

Expertise in custom crafting powertrain controllers for diverse vehicle types

- Specialized feature implementation for Conventional Vehicle, EV, HEV and FCEV
- Cooperative control with ECUs
- Considering fail-safe operation
- Employing diagnostic strategies

Automotive V-Model Process to design systematic development of software & system

- Adopting AUTOSAR to enhance standardization, compatibility and reliability
- Implementing Continuous Integration and Continuous Deployment (CI/CD)
- Leveraging Model-Based Design (MBD) for improved system design and testing
- Integrating Hardware-In-the-Loop Simulation for real-time testing and validation

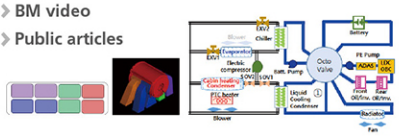


xEV Test of Analysis

Overview

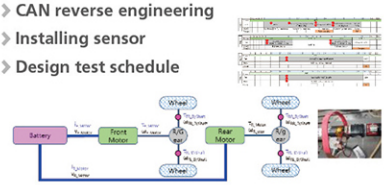
1 Literature Survey

- Patent
- Maintenance manual
- BM video
- Public articles



2 Data Acquisition and Test Design

- CAN reverse engineering
- Installing sensor
- Design test schedule

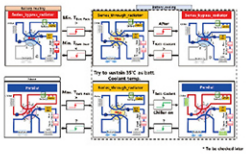


3 Vehicle Test

- Coast down test
- Chassis-dyno test
- Real driving test

4 Vehicle Control Strategy Analysis

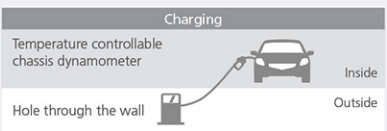
- Analysis system
- Analysis test results
- Analysis control strategy



Vehicle test

Chassis dynamometer test

- Simulate real road driving
  - Driving, slope climbing & charging
- Operating range: -20℃ ~ 55℃



Wheel dynamometer test

- Direct measurement of PT output
  - Performance
  - Efficiency

Cold chamber test

- Operation range: -30℃ ~ 0℃
  - Thermal management
  - Battery charging

EV Charger(~100kW)

Test vehicle list

Tesla
(Model 3, PTC)

BMW
(i3)

BYD
(Tang EV 600d)

BYD
(Seal 4WD)

Hyundai
(IONIQ 6 RWD)

Hyundai
(Kona Electric, 20MY)

Tesla
(Model 3, LFP)

Audi
(e-tron 55 quattro)

BYD
(Song EV pro)

Hyundai
(IONIQ 5 AWD)

KIA
(EV6 GT)

Hyundai
(Kona Electric, 23MY)

Tesla
(Model Y, Heat pump)

Volkswagen
(ID.4 Pro)

XiaoPeng
(P7 4WD)

KIA
(EV6 RWD)

KIA
(EV9 GT-Line)

Chevrolet
(Bolt)

Nissan
(Ariya FWD)

Changan
(SL03)

Hyundai
(NEXO FCEV)

Hyundai
(FC Bus)

Vehicle Engineering

TENERGY's Vehicle Engineering division offers a comprehensive range of engineering services for vehicle development, encompassing everything from initial vehicle design to the development of various production equipment. Leveraging our extensive engineering expertise and robust program management capabilities, we are committed to providing exceptional support throughout the entire vehicle development process. The distinguished vehicle engineering capabilities of TENERGY are designed to guarantee the success of our customers. vehicle launches.

Vehicle design & validation

TENERGY comprehensively addresses the entire spectrum of vehicle design and validation, including the development of prototypes for testing and validation purposes. Through seamless collaboration with Styling, Manufacturing Engineering, and Powertrain Engineering, TENERGY is dedicated to crafting vehicles that stand out in terms of performance, cost-effectiveness, fuel efficiency and other critical parameters. Our integrated approach ensures the development of competitive vehicles that meet and exceed expectations.

Body design

- Body structure & BIW
- Exterior trim
- Door & moving

Interior design

- IP & console
- Interior trim & HVAC
- Seat & restraints

Chassis design

- Front & rear suspension
- Brake & steering system
- Heat & fluid

Electrical design

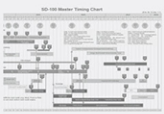
- Lamp & switch
- Wiring harness
- Electric & electronics

Vehicle package

- Layout & key dimension
- Ergonomics & legal
- Digital mock-up

Eng. Management

- Cost/Weight management
- Issue troubleshooting
- Design qualification



Prototype for T&D

- Proto BIW/Vehicle
- Mule car & cubic Jig
- Off-tool prototype

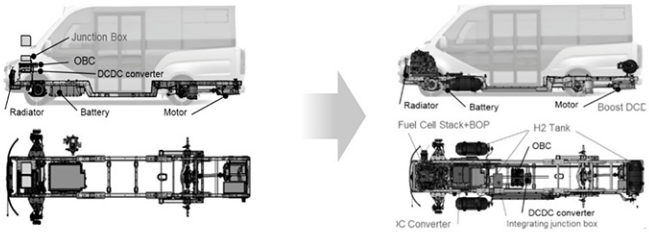
Test & validation

- Test support
- Validation (Virtual/Real)
- Homologation support

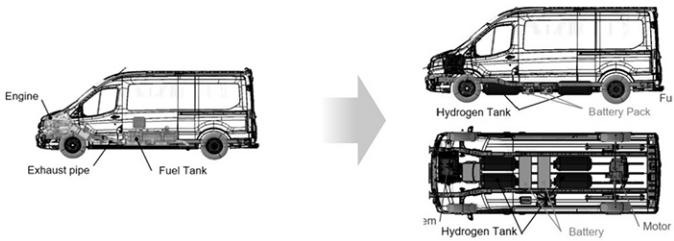
xEV Conversion design

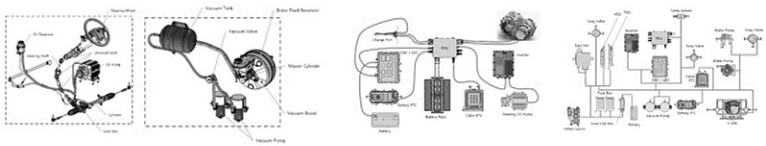
- Package design
- xEV Component development
- System evaluation
- Prototype vehicle test and development

EV to FCEV



ICEV to FCEV





H2 storage & control system design

- Package & detail design
- Prototype system test & development

Vehicle Engineering

ME (Manufacturing Engineering)

TENERGY Manufacturing Engineering (ME) provides Press Dies, Body Assembly equipment, General Assembly equipment, and Injection Mold for automobile production. Leveraging TENERGY's high-level engineering capabilities and excellent project management, we successfully supply high-quality manufacturing tool and equipment and its production output executing from initial Advanced Engineering to the Installation and stabilization of customer production plant within the desired schedule.

Phase I

SE & DESIGN

- Product quality check
- Productivity optimization
- Layout set-up & design

Phase II

FABRICATION

- Material & component procurement
- Tool & equip., structure production
- Machining & assembly

Phase III

QUALITY IMPROVEMENT

- Sample / Line tryout
- Product & production QI
- Pre delivery inspection

Phase IV

INDUSTRIALIZATION

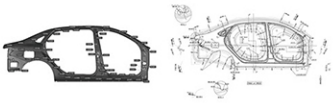
- Packing & delivery
- Home line try-out
- Commissioning / warranty

SE (Simultaneous Engineering)

As major virtual validation together with Computer-Aided Engineering (CAE), TENERGY provides its Simultaneous Engineering (SE) services, leveraging our comprehensive engineering capabilities that span the entirety of vehicle manufacturing. Through this Simultaneous Engineering approach, TENERGY contributes to the development of optimal vehicle designs tailored for good product quality and efficient production. Additionally, we offer expert guidance in formulating process plans that maximize productivity through optimization.

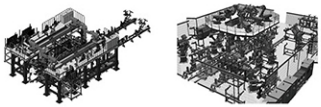
Press SE

- Panel formability & matching
- Blank material optimization
- Press mc study & process planning
- Panel quality check
- Spring-back simulation
- Product design change proposal



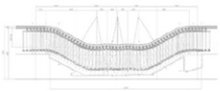
Body SE

- Weldability & gun access
- Line automation & duct location
- MCP/MCS & tolerance
- Cycle time
- Process flow



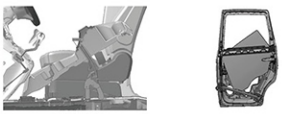
Paint SE

- Anti-corrosion
- ELPO access & fluid drainage
- Dipping & oven
- Water & dust proof



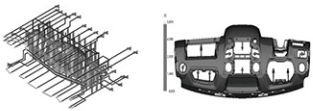
General assembly SE

- Assembly tolerance
- Line balance & logistics
- Workability & tool access
- Visibility, handling & error proof



Injection SE

- Gate & hot runner position study
- Raw material flow
- Production condition
- Plastic formability



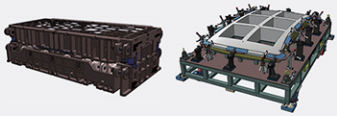
Vehicle Engineering

Tool & Equipment development

Through our Simultaneous Engineering (SE) expertise, TENERGY extends its services to encompass the development of Tools and Equipment for vehicle production. Our engineering capabilities play a pivotal role throughout the entire lifecycle of tool and equipment development, from initial design to the successful installation and commissioning phase for various aspects of the vehicle manufacturing process. TENERGY is committed to delivering top-notch quality in tools and equipment, ensuring that we meet and exceed our customers' expectations within the specified timeframe.

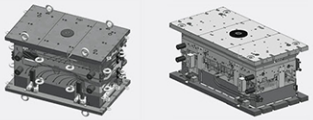
Press Die Development

- Press die
- Checking fixture
- Automation equipment
- Hemming die
- HPF (hot press forming) die



Injection Mold Development

- Injection mold
- Checking fixture



Body Assembly Equipment

- Welding jig & fixture
- Moving system (conveyor etc.)
- Welding robot system
- Hemming equipment

General Assembly Equipment

- Moving system (conveyor etc.)
- Palette & AS/RS
- Automation line

Integrated engineering

TENERGY VE provides the Integrated Engineering solutions to customers based on engineering expertise across all fields of Automotive Engineering. Through this Integrated Engineering approach, effective solutions for issues that may arise from conflicts between various areas of automotive development and manufacturing can be efficiently provided. This enables swift and optimal decision-making. TENERGY has successfully achieved positive outcomes in various projects leveraging these integrated engineering capabilities.

- Body integration : Body design + Press die + Body assembly
- Plastic integration : In / Exterior design + Injection mold

LADA VESTA SW / CROSS

Body integration
- Body design
- Press die

Plastic integration
- In / Exterior design
- Injection mold

HEXA

Body integration
- Body design
- Press die

Plastic integration
- In / Exterior design
- Injection mold

GAZELLE NEXT CABIN

Body integration
- Body design
- Press die
- Body assembly

GAZELLE NEXT VAN

Body integration
- Body design
- Press die
- Body assembly

SOBOL NN

Body integration
- Body design
- Press die
- Body assembly

Engine Design

A lot of recent new engines have showed new variants and limits in every component and combustion type, which have motivated TENERGY to look into the relative merit of each engine.

The design philosophy of TENERGY is to develop well-researched and test-supported criteria to support the design decisions of future engine by investigating the key considerations of new engine design thoroughly and observing their trends carefully.

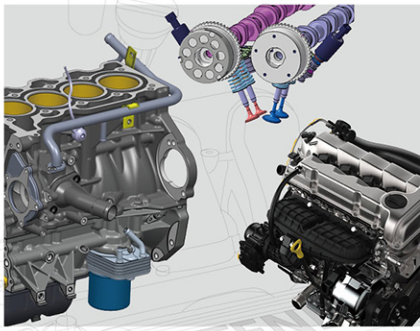
Experienced and highly motivated design engineers work on all types of design projects. And they are effectively supported by our experienced CAE, combustion system, mechanics and electronics teams. Furthermore TENERGY design details always take into account our clients' manufacturing boundary conditions and facilities.

TENERGY mainly uses Pro-E or CATIA and carries out engine design based on 3D model. Theoretical and numerical analyses are also carried out for every optimization. We surely guarantee our design and development outputs after SOP.

WORLD BEST WITH THE BEST

Engine design

- Gasoline engine
- Diesel engine
- Industrial engine
- Hybridization
- 2-stroke engine
- Wankel engine
- Marine engine
- Gen-set engine



Engine design process

Concept design

- Performance definition
- Packaging layout
- Front & timing drive layout
- Valve train layout
- Intake & exhaust system layout
- Cooling & lubrication circuit
- Numeric analysis
  - 1D cycle simulation
  - 1D cooling & lubrication
  - Oil film thickness
  - Torsional vibration
  - Crankshaft, conrod
  - Piston & piston pin
  - Bolt tightening
  - Engine balancing

Definitive design

- Parts & layout design(3D modeling)
- Kinematic/Motion analysis
  - Valve & crank train
- Structural FEA
  - Cylinder block & head
  - Crankshaft, connecting rod
  - Bulkhead & main bearing cap
  - Valve train
- Modal analysis
  - Main structural parts
  - Covers & brackets
- Fatigue life calculation
  - High & low cycle fatigue
- CFD
  - Intake & exhaust ports
  - In-cylinder flow(combustion)
  - Coolant flow
  - Intake & exhaust manifold

Detail design

- Detail parts design(3D modeling)
- 2D drawings
  - Tolerance
  - Roughness
  - Material
  - Machining
  - All information related to production
- Reports
  - Design
  - Analysis

CAE Analysis

TENERGY supports all CAE works required in every engine design stage.

In concept design stage, baseline simulations such as gas exchange calculation, numerical analysis of cranktrain and piston assembly including TV, 1-D cooling and lubrication analysis are carried out.

In detail design stage, structural and dynamic analysis of engine major components are carried out. In addition CFD of coolant and exhaust gas flow and NVH analysis of auxiliary parts are performed.

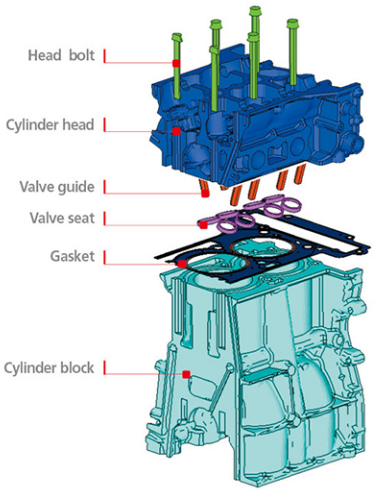
Highly specialized experts with many years of experience in the field of engine development are involved in all CAE works which simulate actual loading conditions as much as possible. Therefore they can offer the optimum solutions for all stages in development process.

TENERGY pays particular attention to CAE works in the scope of development process. CAE works support the whole development process efficiently and enable clients to produce highly qualified engines while achieving shorter development time and lower cost.

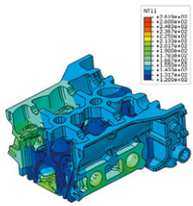
Gas exchange with T / C matching
1-D cooling
1-D lubrication
Valve train kinematics
Bearing load analysis
Torsional vibration
CFD In / Ex. port
CFD in-cylinder flow
CFD coolant flow
CFD intake manifold
CFD exhaust manifold
FEA cylinder head & block compound
FEA cylinder block
FEA cylinder head(LCF)
FEA crankshaft
FEA connecting rod
FEA exhaust manifold(HCF & LCF)
FEA brackets
FEA NVH & modal analysis
FEA intake manifold(plastic)
FEA cylinder head cover(plastic)

FE analysis of cylinder block & head compound

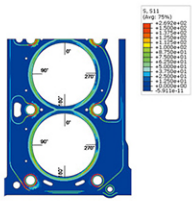
Input data



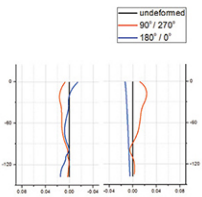
Cylinder head



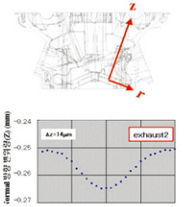
Head gasket



Cylinder bore

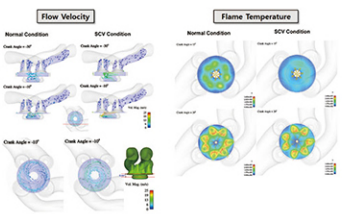


Valve seat

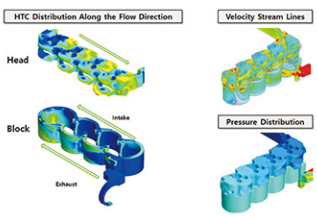


CFD analysis

In-cylinder flow



Coolant flow



TenergySoft

The company TenergySoft is a family of TENERGY providing comprehensive CAE consulting services to a variety of customers all over the world.

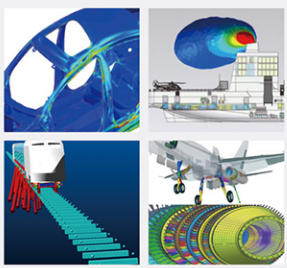
Business areas

Automotive | Defense | Rail | Shipbuilding & offshore | Aerospace etc.

CAE analysis of powertrain	CAE analysis of vehicle	CAE analysis of shipbuilding	CAE analysis of others
Intake & exhaust flow	Suspension K&C	Structural & strength	Landing gear drop
Structural & thermal	Full vehicle R&H	Durability of ship	Composite material
Noise & vibration	Autonomous driving validation	Performance estimation	Railway derailment
-Normal mode & FRF of PT	Virtual test validation	Energy saving device	Fluid-Structure Interaction(FSI)
-Whine & rattle noise of TM	Crash of bumper & hood	Propeller design	Heavy equipment

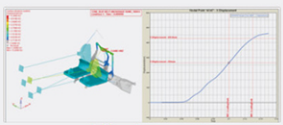
Application fields

- Structure / Fatigue / Nonlinear
- Multi body dynamics
- NVH / Composite / Optimization
- Fluid dynamics / 1D simulation
- Vehicle driving simulator
- Analysis & test process consulting

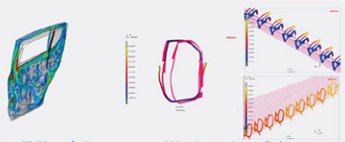


CAE analysis of chassis & vehicle

Car body NVH analysis | Crash analysis of bumper & hood

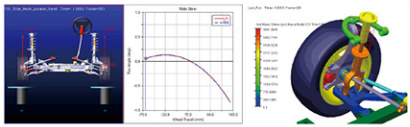


Seat belt anchorage analysis

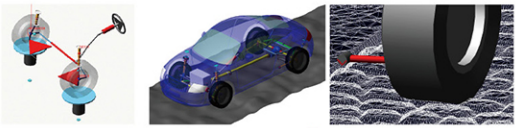


Door NVH analysis | Weather strip analysis

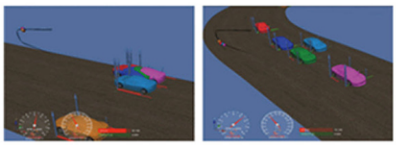
CAE analysis of chassis & vehicle



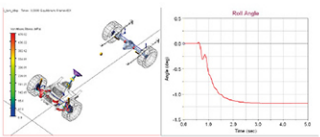
Suspension kinematic analysis



Ride analysis



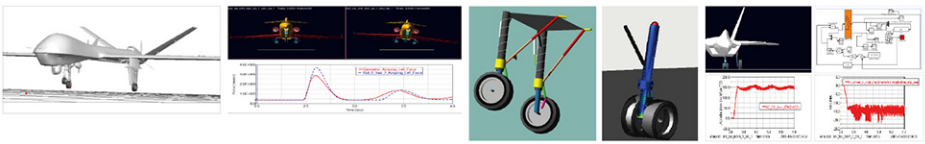
Max performance



Handling analysis

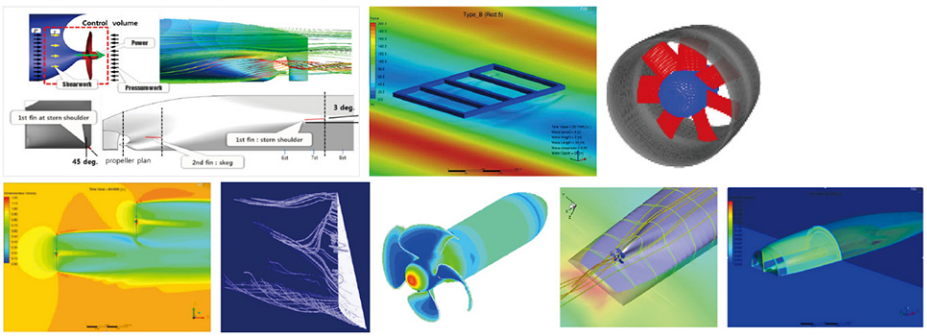
CAE Analysis of machinery

Aerospace analysis



Shipbuilding analysis

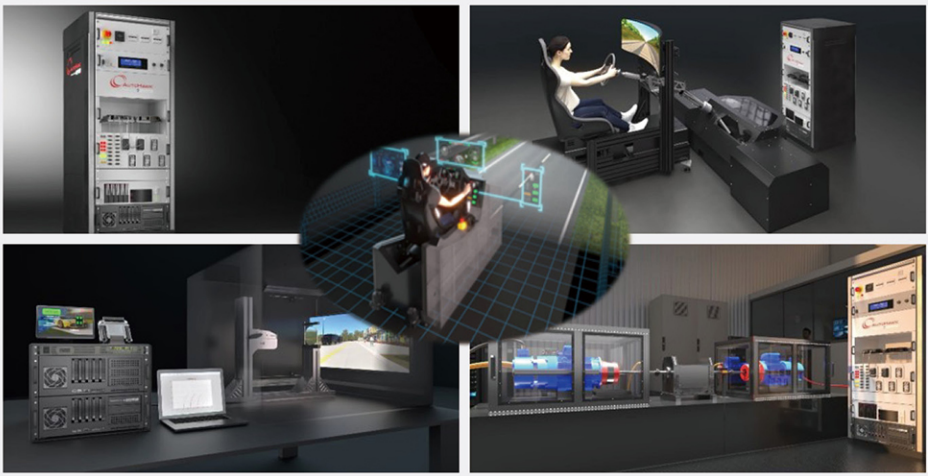
Development of energy saving device / Analysis for performance estimation



TenergySoft - VI-GRADE H/W

HIL(Hardware In the Loop)

Accelerate your development process and prepare for subjective assessment on the driving simulator



STEERING RIG

Equipment

- Steering rig (steering system not included)
- Connection to the Driving Simulator

Applications

- Steering system integration
- EPS calibration
- Steering feeling
- Fault injection
- Benchmarking
- X-by-wire redundancy validation
- ADAS development

BRAKE RIG

Equipment

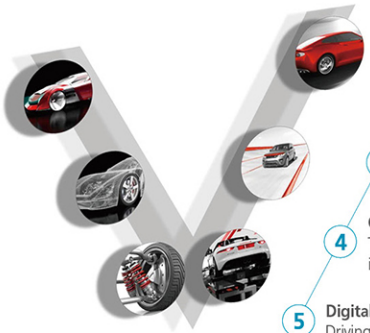
- Brake rig (brake system not included)
- Connection to the Driving Simulator

Applications

- Brake system integration & calibration
- Brake pedal feeling
- Fault injection
- X-by-wire redundancy validation
- Benchmark
- ADAS development

*Possibility of connection with brake rig

AUTOHAWK



1. **Desktop (Offline + SiL + MiL)**
   AutoHawk is used for off-line simulations, DoE, optimization loops
2. **In-lab (HiL + SiL + MiL)**
   These are the typical HiL applications in which a device under test (DUT) is connected to AutoHawk running real-time software
3. **On-sim (HiL + DiL + SiL + MiL)**
   These are HiL applications in which the driver sends inputs to AutoHawk through the simulator - useful to test corner cases and where the closed-loop inputs are essential
4. **On-vehicle (HiL + ViL + SiL + MiL)**
   These are HiL applications where virtual vehicle model runs on the real vehicle with mutual influence
5. **Digital Twins (HiL + DiL + ViL + SiL + MiL)**
   Driving simulator and real vehicle are fully synchronized and they affect each other

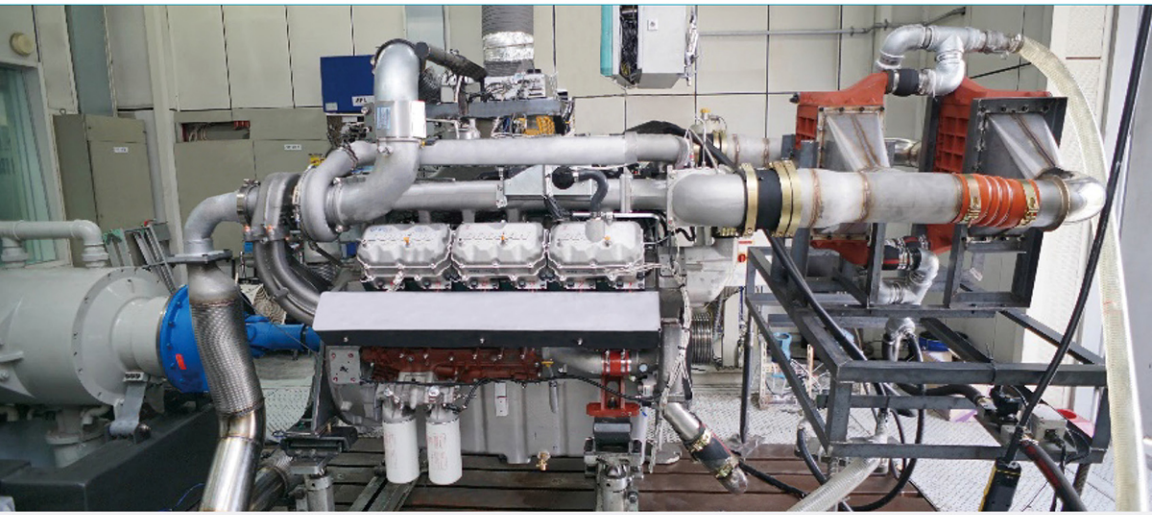
AUTOHAWK 8	AUTOHAWK 16	AUTOHAWK 24	AUTOHAWK AHoB
8-CORE	16-CORE	24-CORE	12-CORE
3.6 GHz Xeon Gold 6244	Two 3.9GHz Xeon Gold 6250	Two 3.6GHz Xeon Gold 6248	One 3.3 GHz Xeon Gold 6242
REDHAWK OS P400 CARD	REDHAWK OS	REDHAWK OS	REDHAWK OS
48 Gb MEMORY	P400 CARD 96 Gb MEMORY	T400 CARD 96 Gb MEMORY	T400 CARD / RTX A4000 96 Gb MEMORY
4 TB DISK CAN/CAN-FD/LIN, FPGA SimWB	4 TB DISK CAN/CAN-FD/LIN, FPGA SimWB	4 TB DISK CAN/CAN-FD/LIN, FPGA SimWB	2 TB DISK 4 CAN SimWB
• Real-time offline simulations with VI-CarRealTime • DoE, Optimization • ECU testing with VI-CarRealTime and tires • Chassis HiL(steering, brake)	• Advanced tires (FTire, CDTire, Swift) • ADAS HiL w/VI-WorldSim • Powertrain/Driveline apps	• Advanced MBS real-time Models • In-vehicle testing	• In-vehicle testing

POSSIBLE INSTALLATIONS:

DESKTOP,
RACK,a
RUGGED (On-Vehicle)

AUTOHAWK ON BOARD (AHoB)

Engine Test & Develop.



Performance development

- Combustion system development
- Turbocharger matching
- Port flow development
- Breathing system development
- EGR, particulate filter, LNT, SCR application for emission
- Engine calibration (torque / air model, base maps)

Mechanical & functional development

- Ventilation test
- Heat balance test
- Piston marking test
- Oil consumption & blow-by development
- Thermal survey test
- Fatigue test

Durability test

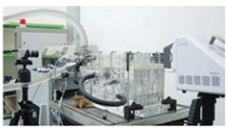
- Full load & full speed test
- Thermal shock test
- Mixed cycle test
- Special purpose test

Benchmarking test

Mechanical & functional test

Telemetry system

Tilting bench



Visualization test

Friction test

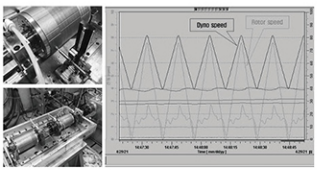
Thermal survey test

Cooling system bench

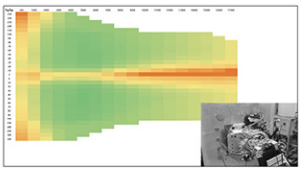
Valve train dynamics

Piston profile measurement

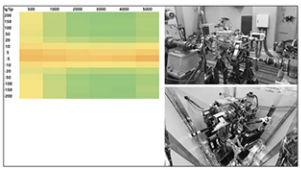
Rotor Core Durability



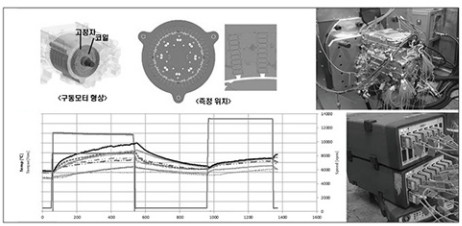
Motor Efficiency Test



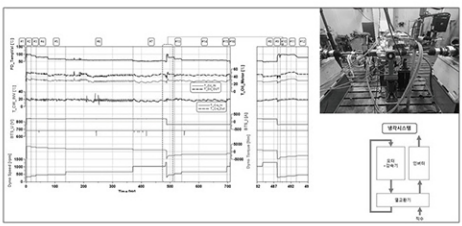
E-PT Efficiency Test



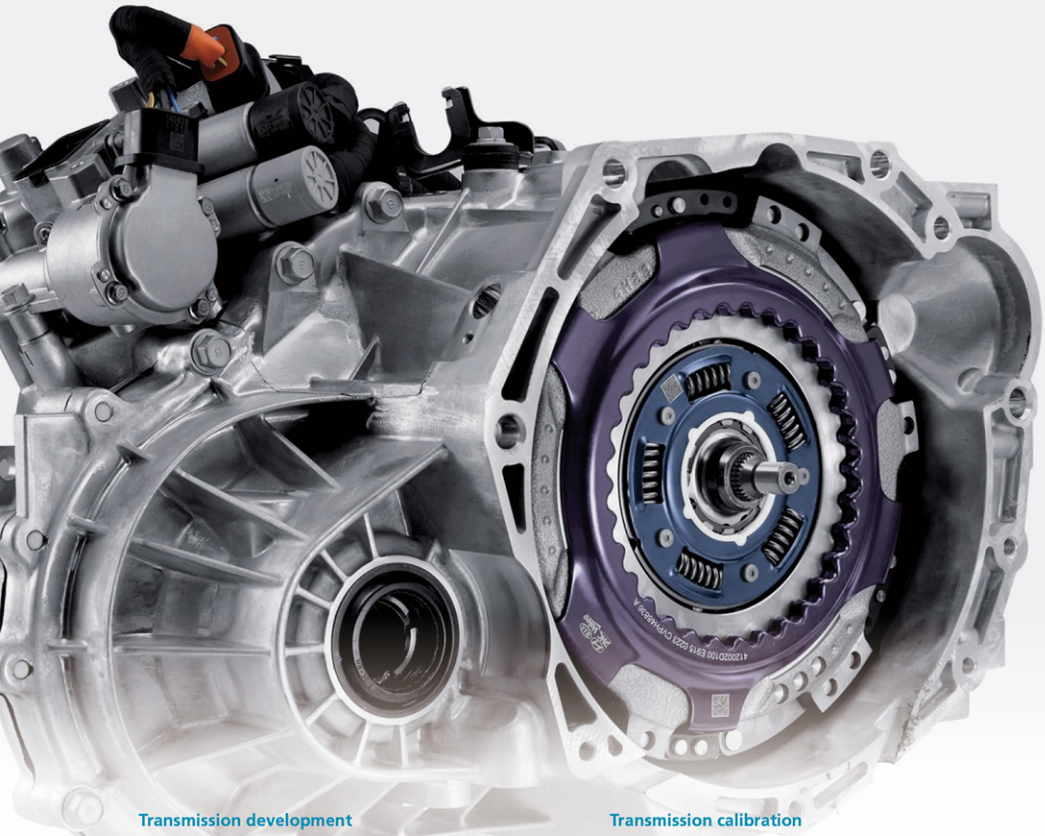
Stator Temp. Measurement



E-PT Durability Test



Transmission Design & Develop.



Transmission development

- Compact layout design of manual transmission and DCT
- Multi-speed gearbox for electric vehicles
- Cost-effective design of transfer case for 4WD
- Development of compact AMT which has no torque interruption
- HDT(Hydro-Dynamic Transmission) with Torque converter
- TCU control logic development

Transmission calibration

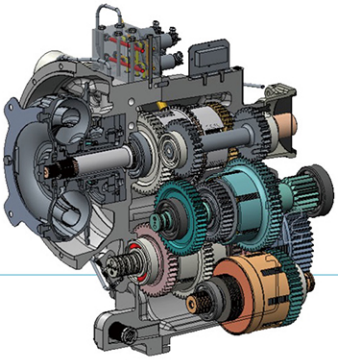
Optimal results for dynamics, performance and fuel consumption

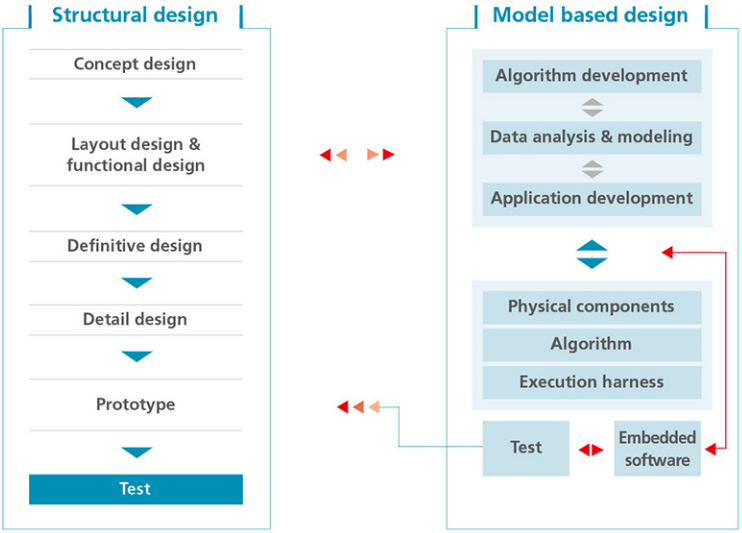
Prototype development, testing and validation

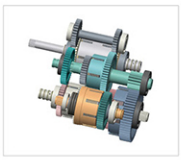
- Rapid prototyping by 3D printing
- Mechanical and functional rig tests
- Transmission dynamometer for transaxle tests with engine

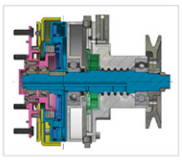
Transmission development process

We meet the requirements on the functionality and efficiency using an effective and start-to-finish process.









EMS Calibration

Target vehicle

- Gasoline
- Diesel
- Hybrid
- EV

Calibration

- Emission
- OBD-II
- Drivability
- After treatment system

Emission calibration

- SULEV, EURO 6/7, China 6 and Tier 4 (Industrial)
- Emission related hardware and component selection
- Optimization of logic and calibration for leaner cold fueling
- UREA-SCR application
- DPF calibration

OBD-II calibration

- OBD-II, EOBD and KOBD regulation

Vehicle benchmarking

- Emission related hardware, logic and calibration
- Fuel economy related hardware, logic and calibration
- Drivability related logic and calibration

Drivability calibration

- Optimum calibration for high drivability index fuel
- Logic development for high drivability index fuel
- Drivability calibration over -30-50° ... ambient temperature

Fuel economy analysis

- Energy Flow-Down Method

Development of advanced fuel economy system and logic

Catalyst bench aging and vehicle durability cycle development corelated with in-use DF

Gasoline SULEV application

Fast light-off control

- H/W side

  Place the catalyst as close as possible to exhaust manifold

  Increase catalyst cell density

- Calibration side to increase heat flux

  Increase Idle engine speed

  Spark timing calibration

  Waste-gate position open control

Reduce engine-out raw emissions

: optimum catalyst heating point and cold start

- Intake/exhaust VVT control
- Injection strategy calibration

  : SOI, EOI, fuel pressure, split injection calibration

NOx conversion efficiency increase

- Fuel cut off condition calibration
- Catalyst purge calibration to increase NOx conversion efficiency
- Lambda control calibration with downstream O2 sensor feedback

Gasoline particulate filter control

GPF model calibration

- DP soot mass with clean filter model
- Engine out soot model
- Soot burning rate model
- GPF temperature model

GPF control

- Passive/active regeneration control

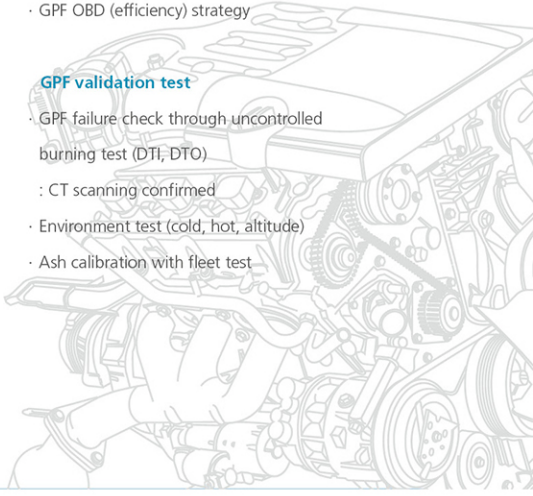
  (Lambda, temperature control)
- Fuel cut off conditon calibration during regeneration
- Soot mass validation (model vs actual mass)
- Soot burning efficiency test
- Service regeneration strategy
- GPF regeneration strategy (duration, coordinator)
- GPF OBD (efficiency) strategy

GPF validation test

- GPF failure check through uncontrolled

  burning test (DTI, DTO)

  : CT scanning confirmed
- Environment test (cold, hot, altitude)
- Ash calibration with fleet test



EMS Calibration

Diesel SCR control

SCR model calibration

- Raw NOx, NO/NO2 ratio modeling
- NOx conversion efficiency modeling
- NH3 loading/slip modeling
- SCR temperature model
- SCR efficiency model

SCR Control

- Heat-up
- NH3 loading target
- Urea dosing schedule
- SCR defrost calibration in cold condition
- Strategy for improvement of emission(RDE, WLTC, NEDC, etc.)
- SCR OBD strategy(efficiency, incorrect urea, consumption, etc.)

SCR validation test

- Environment test(cold, hot, altitude)
- Validation of model accuracy
- Robustness of NOx conversion efficiency in real driving

Diesel particulate filter control

DPF model calibration

- DP soot mass with clean filter model
- Engine out soot model
- Soot burning rate model
- DPF temperature model

DPF control

- Heat-up/active regeneration control
  (air control, post injection control)
- Open & closed loop temperature control
- Transient conditon check and calibration
- Soot mass validation (model vs actual mass)
- Soot burning efficiency test
- Service regeneration strategy
- DPF regeneration strategy (duration, coordinator)
- DPF OBD (PM sensor, efficiency) strategy

DPF validation test

- DPF failure check through uncontrolled
  burning test (DTI, DTO)
  : CT scanning confirmed
- Environment test (cold, hot, altitude)
- Oil dilution & ash check with fleet test

Diesel EURO 7 / China 6

Additional challenge for better fuel consumption

· Thermal management
  - Integrated thermal management 3-way valve control(block, radiator, heater)
  - Split cooling circuit
  - Optimized temperature of each part
· Weight reduction
  - Aluminum cylinder block
· Friction reduction
  - Piston & ring design optimization
  - Crankshaft balance weight optimization
  - Variable oil pump integrated with vacuum pump
  - Timing belt instead of chain system
  - Camcarrier-camshaft module
  - Crank offset
  - Roller rocker arm
  - Switchable water pump or electrically controlled thermostat

After treatment system

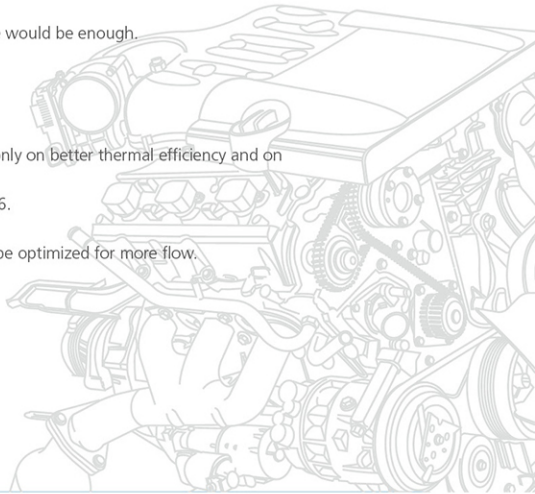
· SCR system will be in multiple locations and the total size will be larger
· Urea injection will be multi-point injection.
· DPF would not need active regeneration any more, only passive type would be enough.
· Electrically heated catalyst could be used for cold start emission.

Combustion system

· With enhanced SCR system, engine developmint could be focused only on better thermal efficiency and on reducing PM, no longer on reducing NOx emission as before.
· Compression ratio would be raised to around 18 from current 15~16.
· EGR would be used limitedly or the system even may be deleted.
· High swirl would be required less than before, therefore port could be optimized for more flow.

Electrification

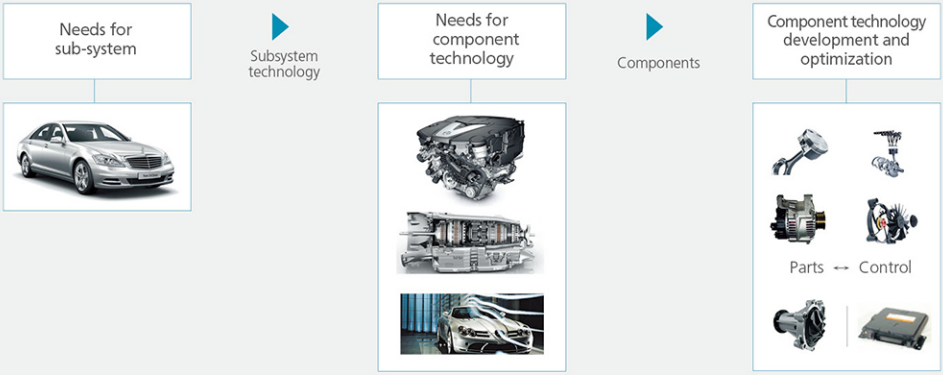
· 48V mild hybrid system will used.(P0~P2)
· EHC could be effective by 48V system



Fuel Economy Analysis

Principle of Energy Flow-Down Method

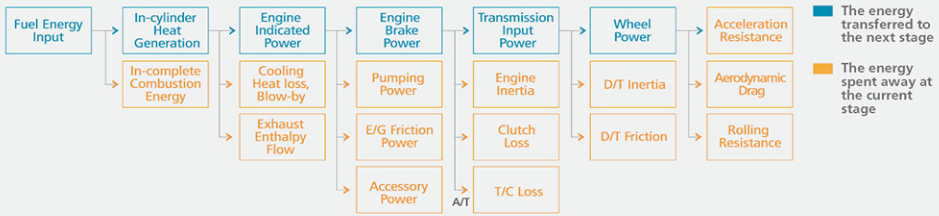
To improve fuel economy of your car, understanding of engine + T/M + vehicle interaction and control strategy (ECU, TCU) are very Important



Benefits of Energy Flow-Down Method

- Energy Flow-Down Method can analyze the fuel consumption and contribution of each component and ECU/TCU control data through systematic approach.
- Client can have the whole view for the quantitative fuel consumption and contribution of each component.
- Client can recognize the weak and strong points against target vehicle.
- Client can understand how top maker optimizes every component and control data to improve fuel economy.
- Client can make catch-up plan of short, mid, long term in the most efficient cost.

$$\dot{m}_f Q_{LHV,f} = \dot{Q}_{in\text{-}comb} + \dot{Q}_{cool} + \dot{Q}_{exh} + P_{pumping} + P_{ef} + P_{accessory} + P_{ei} + P_{tcl(A/T)} + P_{dcl(A/T)} + P_{dtf} + P_{dti} + P_R + P_A + P_{vi} + \dot{Q}_{etc}$$



How we do, What you can get!

Measurement items	Results	Recommendation
· Combustion pressure · Ignition signal · Engine speed · Vehicle speed · Manifold absolute pressure · Air/Fuel ratio · Battery voltage & current · Alternator current · Cooling fan current · Brake pedal signal · Accelerator pedal signal · Throttle angle signal · Coolant temperature · Engine oil temperature · Injection pulse · Fuel rail pressure · Fuel temperature · Exhaust gas temperature · Turbine rpm · Output shaft rpm · Engine inertia @ lift · Drivetrain friction @ lift · Drivetrain inertia @ lift · Engine friction @ bench · Torque converter characteristics @ MAD · Injector characteristics @ rig · Power steering friction @ rig · Each gear driving resistance @ test load (if necessary) · Shift pattern & lockup area @ MAD	· Indicated thermal efficiency · Incomplete combustion loss · Pumping loss · Engine friction loss · Alternator loss · Power steering loss · Engine inertia loss · Torque converter base loss · Torque converter slip loss · Braking loss · Drive train friction loss · Drive train inertia loss · Clutch loss · Vehicle inertia loss · Rolling resistance loss (f0) · Aerodynamic resistance loss (f2) · Pilot/Main injection timing (diesel) · Spark timing (gasoline) · Idle RPM · Total fuel cut time · Total cycle number · Cooling fan loss · Total part load full lockup time · Part load speed ratio distribution · Total driving time at each gear · Shift pattern · Energy management system logic · Neutral control logic · Deceleration lockup logic · Ne elevation logic	· Logic & calibration strategy · Engine hardware strategy - Friction improvement - System application strategy (Intake CVVT, Dual CVVT, Turbo, GDI, etc.) · Characteristic of engine (BSFC, mechanical friction, pumping friction, engine inertia) · Transmission hardware strategy · Shift pattern & lockup zone strategy · Torque converter selection strategy · Gear ratio selection strategy · Transmission related loss (Drivetrain friction loss, slip loss, fuel consumption at each gear) · Vehicle thermal management strategy · Vehicel electrical load strategy · Vehicle energy save strategy · Rolling resistance reduction strategy · Aerodynamic resistance reduction strategy

Big Data

1. Data Collection(IIoT & Edge Device)

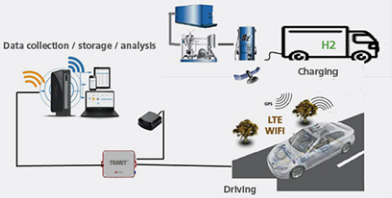
Vehicle Data Engineering & Management Solution

IIoT & edge device for vehicle data

- Data collection CAN/XCP communication with vehicle
  *.dbc file supporting for hundreds vehicles, A2L available
- Extendable for various sensing
- Easy Installation & usage
- Not only vehicles, machinery, marin, non-road, etc.

Applications

- Telematics
- FOT (field operational test)
- Performance test



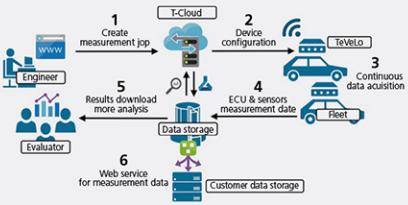
Description	TeNeT
Purpose	Data logging device via vehicle networks
Operating system	Linux
Processor/memory	ARM-A72 CPU 2.5GHz/8GB
External memory	32GB SD card
Interface	UDS, OBD2, TP, GMLAN, BMW(7 Byte) with CAN(FD)/LAN
Measurement	11bit standard diagnostic/29bit extended CAN bus monitoring with dbc file/external trigger input
Wake up	CAN signal/Key on
Sensors	1x GPS
Ports	4x USB/2x CAN/1x LAN/HDMI (option, 4x CAN)
Communication	WiFi/4G LTE
Sub-device	4 x 8 ch AI

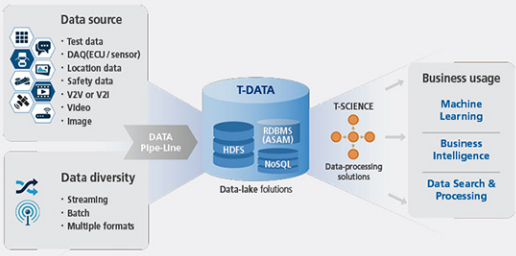
2. Data Analysis & Application(Bigdata Platform)

Field Data Collection Service to On Promise (Sever) or Cloud. We Provide Platform and effective transfer for Big amount of Data with various solution.

T Data(cloud) & T-Mine(on premise)

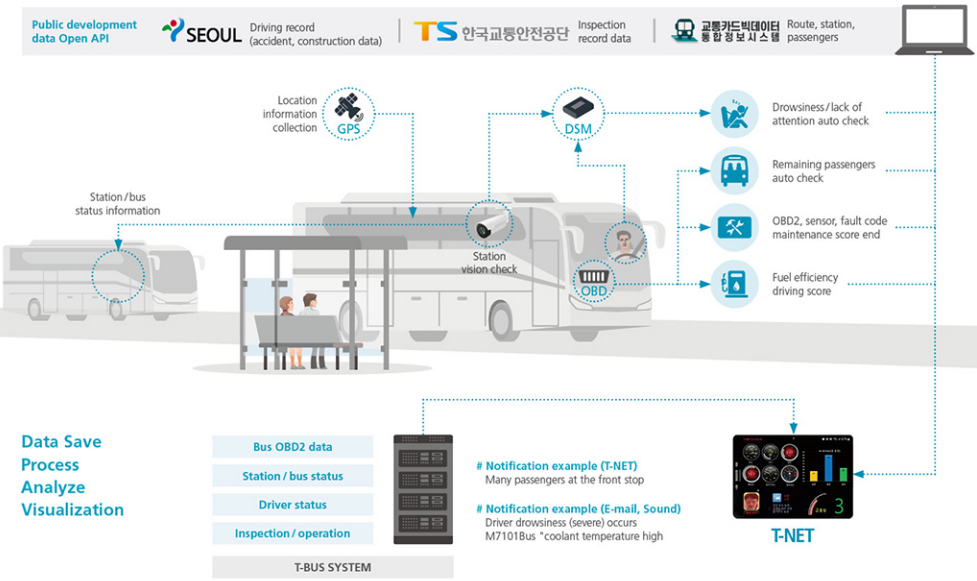
- Test & measurement data management
- Test measurement data validation & evaluation
- Test efficiency & project management
- Road data monitoring





3. Improved bus fuel efficiency, safety, and environment (Bigdata Platform)

Data Collection



System Utilization

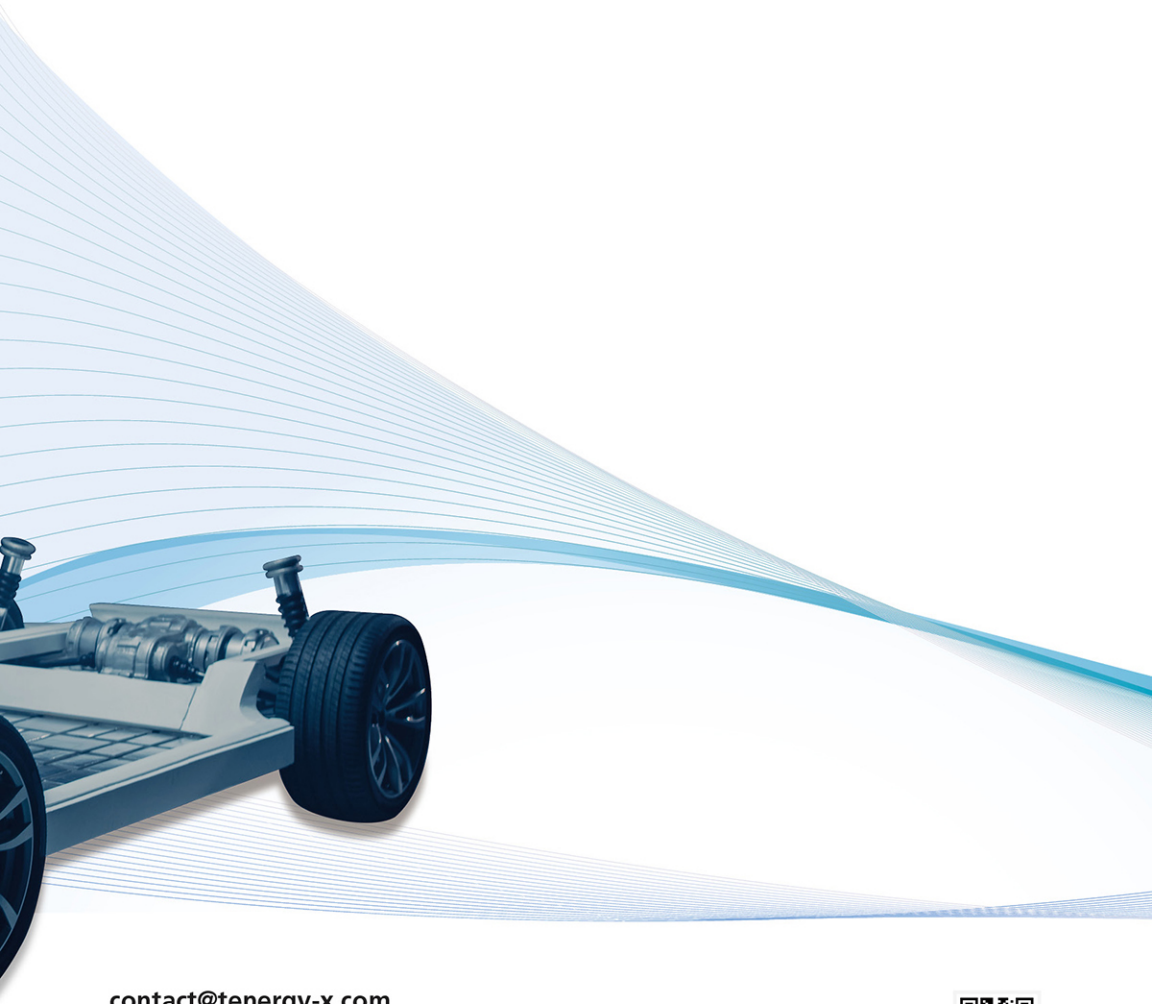
Real-time integrated control

Smart preventive maintenance

Integrated data analysis

Effect	Description	Function
Safety	Drowsiness/ lack of attention auto check	DSM vision AI
Maintenance	OBD2 Sensor, fault code maintenance score	CBM
On-time dispatch	Check the status of passengers at buses/stops	T-BUS vision AI
Fuel efficiency	Utilizing sudden acceleration/ sudden stop data	ECO BUS
Environment	Improved fuel efficiency and reduced emissions	T-BUS

World Best with The Best



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