

Greenhouse Gas Emissions of a Hydrogen Engine for Automotive Application through Life Cycle Assessment

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1. Life cycle inventories

1.1 Raw material acquisition and pre-processing

Table S1 Raw material acquisition and pre-processing

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Block_Material	1 p	1 p	See Table S2
Head_Material	1 p	1 p	See Table S6
Crank-Rotating_Material	1 p	1 p	See Table S9
Crank-Reciprocating_Material	1 p	1 p	See Table S17
Lube & Vent_Material	1 p	1 p	See Table S20
Valvetrain_Material	1 p	1 p	See Table S37
Cooling_Material	1 p	1 p	See Table S50
Accessory Drive_Material	1 p	1 p	See Table S52
Crancking System	1 p	1 p	See Table S56
Fuel Delivery System	1 p	1 p	See Table S61
Aftertreatment_Material	1 p	1 p	See Table S63
Air Delivery_Material	1 p	1 p	See Table S67
Exhaust_Material	1 p	1 p	See Table S68
Turbo Charging_Material	1 p	1 p	See Table S69

1.1.1 Block_Material

Table S2 Block_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
BLOCK-ENG_Material	1 p	1 p	See Table S3
CAP-CR/SHF BRG_material	5 p	5 p	See Table S4
ADAPTER ASM-T/CV HSG_Material	1 p	1 p	See Table S5

Table S3 BLOCK-ENG_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Cast Iron	159 kg	159 kg	Cast iron {GLO} market for APOS, U

Table S4 CAP-CR/SHF BRG_material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Cast Iron	2.896 kg	2.896 kg	Cast iron {GLO} market for APOS, U

Table S5 ADAPTER ASM-T/CV HSG_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Cast aluminum	5.533 kg	5.533 kg	Aluminum, cast alloy {GLO} market for APOS, U

1.1.2 Head_Material

Table S6 Head_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
HEAD-CYL_material	2 p	2 p	See Table S7
GASKET-CYL HD_Material	2 p	2 p	See Table S8

Table S7 HEAD-CYL_material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Cast aluminum	18.6 kg	18.6 kg	Aluminum, cast alloy {GLO} market for APOS, U

Table S8 GASKET-CYL HD_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Stainless steel	0.39 kg	0.39 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U

1.1.3 Crank-Rotating_Material

Table S9 Crank-Rotating_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
CRANKSHAFT_Material	1 p	1 p	See Table S10
BALANCER-CR/SHF_Material	1 p	1 p	See Table S11
FLYWHEEL ASM_Material	1 p	1 p	See Table S15
PLATE-A/TRNS FLEX_Material	1 p	1 p	See Table S16

Table S10 CRANKSHAFT_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel	61.88 kg	61.88 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S11 BALANCER-CR/SHF_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
BALANCER-CR/SHF_Crankshaft pulley_Material	1 p	1 p	See Table S12
BALANCER-CR/SHF_Machined Hub_Material	1 p	1 p	See Table S13
BALANCER-CR/SHF_Elastomer_Material	1 p	1 p	See Table S14

Table S12 BALANCER-CR/SHF_Crankshaft pulley_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Cast iron	2.19 kg	2.19 kg	Cast iron {GLO} market for APOS, U

Table S13 BALANCER-CR/SHF_Machined Hub_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Cast iron	6.25 kg	6.25 kg	Cast iron {GLO} market for APOS, U

Table S14 BALANCER-CR/SHF_Elastomer_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Rubber EPDM	0.24 kg	0.24 kg	Synthetic rubber {GLO} market for APOS, U

Table S15 FLYWHEEL ASM_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Flywheel_Material	13.75 kg	13.75 kg	Cast iron {GLO} market for APOS, U
Ring Gear_Material	2 kg	2 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S16 PLATE-A/TRNS FLEX_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Stainless steel	1.6 kg	1.6 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U

1.1.4 Crank-Reciprocating_Material

Table S17 Crank-Reciprocating_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Piston ASM_Material	8 p	8 p	See Table S18
Conrod_Material	8 p	8 p	See Table S19

Table S18 Piston ASM_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Aluminum, cast alloy	0.991 kg	0.991 kg	Aluminum, cast alloy {GLO} market for APOS, U

Table S19 Conrod_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low alloyed	1.98 kg	1.98 kg	Steel, low-alloyed {GLO} market for APOS, U

1.1.5 Lube & Vent_Material

Table S20 Lube & Vent_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
COOLER ASM-ENG OIL_Material	1 p	1 p	See Table S21
COVER ASM-VLV RKR ARM (LH)_Material	1 p	1 p	See Table S28
COVER ASM-VLV RKR ARM (RH)_Material	1 p	1 p	See Table S29
PAN ASM-UPR OIL_Material	1 p	1 p	See Table S30
PAN ASM-OIL_Material	1 p	1 p	See Table S31
PUMP ASM-OIL_Material	1 p	1 p	See Table S37

Table S21 COOLER ASM-ENG OIL_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Housing_Material	1 p	1 p	See Table S22
Flange_Material	1 p	1 p	See Table S23
Adapter_material	1 p	1 p	See Table S24
Turbolizer_Material	19 p	19 p	See Table S25
COOLER ASM-ENG OIL_Lower plate	19 p	19 p	See Table S26
COOLER ASM-ENG OIL_Upper plate	19 p	19 p	See Table S27

Table S22 Housing_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Aluminum, cast	1.287 kg	1.287 kg	Aluminum, cast alloy {GLO} market for APOS, U

Table S23 Flange_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	0.37 kg	0.37 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S24 Adapter_material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Aluminum, cast	2.37 kg	2.37 kg	Aluminum, cast alloy {GLO} market for APOS, U

Table S25 Turbolizer_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	0.19 kg	0.19 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S26 COOLER ASM-ENG OIL_Lower plate (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Stainless steel	0.049 kg	0.049 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U

Table S27 COOLER ASM-ENG OIL_Upper plate (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Stainless steel	0.051 kg	0.051 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U

Table S28 COVER ASM-VLV RKR ARM (LH)_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Aluminum, cast	5,50 kg	5,50 kg	Aluminum, cast alloy {GLO} market for APOS, U

Table S29 COVER ASM-VLV RKR ARM (RH)_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Aluminum, cast	4.66 kg	4.66 kg	Aluminum, cast alloy {GLO} market for APOS, U

Table S30 PAN ASM-UPR OIL_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Aluminum, cast	6.04 kg	6.04 kg	Aluminum, cast alloy {GLO} market for APOS, U

Table S31 PAN ASM-OIL_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Stainless steel	4.27 kg	4.27 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U

Table S32 PUMP ASM-OIL_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
PUMP ASM-OIL Housing_material	1 p	1 p	See Table S33
PUMP ASM-OIL Cover_material	1 p	1 p	See Table S34
PUMP ASM-OIL Shaft_material	2 p	2 p	See Table S35
PUMP ASM-OIL Gear_material	3 p	3 p	See Table S36

Table S33 PUMP ASM-OIL Housing_material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Aluminum, cast	0.39 kg	0.39 kg	Aluminum, cast alloy {GLO} market for APOS, U

Table S34 PUMP ASM-OIL Cover_material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Aluminum, cast	0.53 kg	0.53 kg	Aluminum, cast alloy {GLO} market for APOS, U

Table S35 PUMP ASM-OIL Shaft_material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	0.12 kg	0.12 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S36 PUMP ASM-OIL Gear_material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	0.24 kg	0.24 kg	Steel, low-alloyed {GLO} market for APOS, U

1.1.6 Valvetrain_Material

Table S37 Valvetrain_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
CAMSHAFT ASM_Material	1 p	1 p	See Table S38

GEAR ASM-CM/SHF_Material	1 p	1 p	See Table S39
ROD-VLV PUSH_Material	16 p	16 p	See Table S40
SHAFT ASM-VLV RKR ARM (W/ ARM)_Material	2 p	2 p	See Table S41
GEAR-CR/SHF_Material	1 p	1 p	See Table S42
GEAR-OIL PUMP_Material	1 p	1 p	See Table S43
SPRING-VLV (EXH)_Material	16 p	16 p	See Table S44
SPRING-VLV (INT)_Material	16 p	16 p	See Table S45
VALVE-EXH_Material	16 p	16 p	See Table S44
VALVE-INT_Material	16 p	16 p	See Table S45
Gear Water Pump_Material	1 p	1 p	See Table S48
Fuel Pump Gear_Material	1 p	1 p	See Table S49

Table S38 CAMSHAFT ASM_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	7.4 kg	7.4 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S39 GEAR ASM-CM/SHF_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
GEAR ASM-CM/SHF Main gear_Material	2.1 kg	2.1 kg	Steel, low-alloyed {GLO} market for APOS, U
GEAR ASM-CM/SHF Back gear_Material	0.7 kg	0.7 kg	Steel, low-alloyed {GLO} market for APOS, U
GEAR ASM-CM/SHF Spring_Material	0.7 kg	0.7 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S40 ROD-VLV PUSH_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Rod Tube_Material	0.083 kg	0.083 kg	Steel, low-alloyed {GLO} market for APOS, U
Socket_Material	0.018 kg	0.018 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S41 SHAFT ASM-VLV RKR ARM (W/ ARM)_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Rocker arm_Material	2.24 kg	2.24 kg	Steel, low-alloyed {GLO} market for APOS, U
Shaft rkr arm_Material	2,5 kg	2,5 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S42 GEAR-CR/SHF_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	1.47 kg	1.47 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S43 GEAR-OIL PUMP_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	1.46 kg	1.46 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S44 SPRING-VLV (EXH)_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	0.088 kg	0.088 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S45 SPRING-VLV (INT)_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	0.084 kg	0.084 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S46 VALVE-EXH_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	0.079 kg	0.079 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S47 VALVE-INT_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	0.094 kg	0.094 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S48 Gear Water Pump_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	0.59 kg	0.59 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S49 Fuel Pump Gear_Material (1 p)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	0.51 kg	0.51 kg	Steel, low-alloyed {GLO} market for APOS, U

1.1.7 Cooling_Material

Table S50 Cooling_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
PUMP ASM- WAT_Material	1 p	1 p	See Table S51

COVER ASM-ENG FRT_Material	2.95 kg	2.95 kg	Aluminum, cast alloy {GLO} market for APOS, U
HOUSING-ENG COOL THERM_Material	1.31 kg	1.31 kg	Aluminum, cast alloy {GLO} market for APOS, U
HEATER ASM-ENG COOL_Material	0.72 kg	0.72 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
THERMOSTAT ASM- ENG COOL_Material	2.47 kg	2.47 kg	Aluminum, cast alloy {GLO} market for APOS, U

Table S51 PUMP ASM-WAT_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Aluminum, cast	2.45 kg	2.45 kg	Aluminum, cast alloy {GLO} market for APOS, U
Stainless steel	0.99 kg	0.99 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U

1.1.8 Accessory Drive_Material

Table S52 Accessory Drive_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
BRACKET ASM-A/C CMR & P/S PUMP_Material	3.94 kg	3.94 kg	Aluminum, cast alloy {GLO} market for APOS, U
BRACKET ASM- GEN1_Material	3.75 kg	3.75 kg	Aluminum, cast alloy {GLO} market for APOS, U
TENSIONER ASM-DRV BELT_Material	1 p	1 p	See Table S53
PULLEY ASM-FAN (W/ BRG)_Material	1 p	1 p	See Table S54
TENSIONER ASM-DRV BELT 2nd_Material	1 p	1 p	See Table S55
BELT-ACSRY DR PRM_Material	0.4066 kg	0.4066 kg	Synthetic rubber {GLO} market for APOS, U
PULLEY ASM-DRV BELT IDLER_Material	0.142 kg	0.142 kg	Cast iron {GLO} market for APOS, U
BELT-ACSRY DR AUX_Material	0.107 kg	0.107 kg	Synthetic rubber {GLO} market for APOS, U
BRACKET ASM-GEN2 (alternator A/C)_Material	0.51 kg	0.51 kg	Aluminum, cast alloy {GLO} market for APOS, U

Table S53 TENSIONER ASM-DRV BELT_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
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Aluminum, cast	0.60 kg	0.60 kg	Aluminum, cast alloy {GLO} market for APOS, U
Steel, low-alloyed	0.16 kg	0.16 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S54 PULLEY ASM-FAN (W/ BRG)_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Aluminum, cast	2.64 kg	2.64 kg	Aluminum, cast alloy {GLO} market for APOS, U
Steel, low-alloyed	0.88 kg	0.88 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S55 TENSIONER ASM-DRV BELT_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Aluminum, cast	0.43 kg	0.43 kg	Aluminum, cast alloy {GLO} market for APOS, U
Steel, low-alloyed	0.16 kg	0.16 kg	Steel, low-alloyed {GLO} market for APOS, U

1.1.9 Cranking System

Table S56 Cranking System

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
STARTER ASM	1 p	1 p	See Table S61

Table S57 STARTER ASM

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
STARTER ASM_Solenoid assembly_Material	1 p	1 p	See Table S58
STARTER ASM_Pinion assembly	1 p	1 p	See Table S59
STARTER ASM_Gear reduction assembly	0.388 kg	0.388 kg	Steel, low-alloyed {GLO} market for APOS, U
STARTER ASM_Motor assembly	1 p	1 p	See Table S60
STARTER ASM_Front bracket	0.833 kg	0.833 kg	Aluminium, cast alloy {GLO} market for APOS, U

Table S58 STARTER ASM_Solenoid assembly_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Housing	0.23 kg	0.23 kg	Steel, low-alloyed {GLO} market for APOS, U
Cover	0.047 kg	0.047 kg	Nylon 6-6 {RoW} market for nylon 6-6 APOS, U

Pinion coil	0.0156 kg	0.0156 kg	Nylon 6-6 {RoW} market for nylon 6-6 APOS, U
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Table S59 STARTER ASM_Pinion assembly

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Bracket	0.222 kg	0.222 kg	Steel, low-alloyed {GLO} market for APOS, U
Overrunning clutch	0.27 kg	0.27 kg	Steel, low-alloyed {GLO} market for APOS, U
Output shaft	0.22 kg	0.22 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S60 STARTER ASM_Motor assembly

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Yoke housing	0.531 kg	0.531 kg	Steel, low-alloyed {GLO} market for APOS, U
Armature	1.081 kg	1.081 kg	Steel, low-alloyed {GLO} market for APOS, U
Magnets	0.061 kg	0.061 kg	
Lamella commutator			
Wire			

1.1.10 Fuel Delivery System

Table S61 Fuel Delivery System

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
PUMP ASM-F/INJN	1 p	1 p	See Table S62
RAIL ASM-F/INJN FUEL	7.2 kg	7.2 kg	Steel, low-alloyed {GLO} market for APOS, U
BRACKET-F/INJR	1.04 kg	1.04 kg	Steel, low-alloyed {GLO} market for APOS, U

Table S62 PUMP ASM-F/INJN

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Steel, low-alloyed	2.5 kg	2.5 kg	Steel, low-alloyed {GLO} market for APOS, U
Aluminum, cast	2.01 kg	2.01 kg	Aluminum, cast alloy {GLO} market for APOS, U

1.1.11 Aftertreatment_Material

Table S63 Aftertreatment_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
CONVERTER ASM-OXIDN CTLTC (uf2DOC/DPF)_Material	1 p	1 p	See Table S64

CONVERTER ASM- OXIDN CTLTC (ccDOC)_Material	1 p	1 p	See Table S65
CONVERTER ASM-NOX CTLTC (uf1SCR)_Material	1 p	1 p	See Table S66

Table S64 CONVERTER ASM-OXIDN CTLTC (uf2DOC/DPF)_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Inler outler cone	1.43 kg	1.43 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Inler inner cone	1.15 kg	1.15 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
DOC – DPF shell	4.21 kg	4.21 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
MID BED INNER ring	0.37 kg	0.37 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Outlet inner cone	1.35 kg	1.35 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Outlet outler cone	1.6 kg	1.6 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
EGR Frange	0.499 kg	0.499 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U

Table S65 CONVERTER ASM-OXIDN CTLTC (ccDOC)_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Inlet flange	2.03 kg	2.03 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Inlet doc – part 1	1.05 kg	1.05 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Inlet doc – part 2	1.05 kg	1.05 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Doc shell	2.66 kg	2.66 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Outlet inner cone	0.936 kg	0.936 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U

Outlet outler cone	1.29 kg	1.29 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Outlet pipe	1.13 kg	1.13 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Outlet flange	1.89 kg	1.89 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Bracket welded	1.25 kg	1.25 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Bracket screwed	1.46 kg	1.46 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U

Table S66 CONVERTER ASM-NOX CTLTC (uf1SCR)_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Inler outler cone	1.70 kg	1.70 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Inler inner cone	1.37 kg	1.37 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
SCR shell	5.70 kg	5.70 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Outlet inner cone	1.5 kg	1.5 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Outlet outler cone	1.9 kg	1.9 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U

1.1.12 Air Delivery_Material

Table S67 Air Delivery_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
MANIFOLD ASM-UPR INT_Material	3.01 kg	3.01 kg	Aluminium, cast alloy {GLO} market for APOS, U
MANIFOLD ASM-LWR INT_Material	2.10 kg	2.10 kg	Aluminium, cast alloy {GLO} market for APOS, U
BODY ASM- THROT_Material	0.508 kg	0.508 kg	Aluminium, cast alloy {GLO} market for APOS, U
	0.229 kg	0.229 kg	Steel, low-alloyed {GLO} market for APOS, U

1.1.13 Exhaust_Material

Table S68 Exhaust_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
MANIFOLD-EXH (side A)_Material	5.83 kg	5.83 kg	Cast iron {GLO} market for APOS, U
MANIFOLD-EXH (side B)_Material	4.13 kg	4.13 kg	Cast iron {GLO} market for APOS, U
VALVE-EGR_Material	0.725 kg	0.725 kg	Aluminium, cast alloy {GLO} market for APOS, U
	1.6 kg	1.6 kg	Cast iron {GLO} market for APOS, U
VALVE-EGR VLV CLR BYPASS_Material	2.32 kg	2.32 kg	Aluminium, cast alloy {GLO} market for APOS, U
COOLER ASM-EGR_Material	2.04 kg	2.04 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
	3.13 kg	3.13 kg	Aluminium, cast alloy {GLO} market for APOS, U

1.1.14 Turbocharging_Material

Table S69 Turbocharging_Material

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
TURBOCHARGER ASM-CMPR AIR INT_Material	10.39 kg	10.39 kg	Cast iron {GLO} market for APOS, U
	2.80 kg	2.80 kg	Aluminium, cast alloy {GLO} market for APOS, U

1.2 Manufacturing

Table S70 Manufacturing, inputs per 1 engine

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Electricity	98.5 MJ	98.5 MJ	Low voltage CN
Electricity	187 MJ	187 MJ	Low voltage DE
Electricity	16.4 MJ	16.4 MJ	Low voltage JP
Electricity	527 MJ	527 MJ	Low voltage MX
Electricity	2880 MJ	2880 MJ	Low voltage US
Polyethylene	4.51 kg	4.51 kg	Market for polyethylene, high density, granulate {GLO}
Silica sand	277 kg	277 kg	Market for silica sand {GLO}
Casting aluminum	0.72 kg	0.72 kg	Aluminium, primary, ingot {RoW} production without scrap and electricity

Cold tempering	5.11 kg	5.11 kg	Impact extrusion of aluminum cold tempering {RoW}
Cold tempering	26.9 kg	26.9 kg	Impact extrusion of steel, cold, 1 strokes {RoW} processing without (after) heat treatment, (pre) heating, and deformation stroke pathway
Cold tempering	6.38 kg	6.38 kg	Impact extrusion of steel, cold, 2 strokes {RoW} processing without (after) heat treatment, (pre) heating, and deformation stroke pathway
Hot tempering	13.7 kg	13.7 kg	Impact extrusion of steel, hot, 1 strokes {RoW} processing without (after) heat treatment, (pre) heating, and deformation stroke pathway
Hot tempering	81.1 kg	81.1 kg	Impact extrusion of steel, hot, 2 strokes {RoW} processing without (after) heat treatment, (pre) heating, and deformation stroke pathway
Hot tempering	7.2 kg	7.2 kg	Impact extrusion of steel, hot, 5 strokes {RoW} processing without (after) heat treatment, (pre) heating, and deformation stroke pathway
Injection moulding	0.7 kg	0.7 kg	Injection moulding {RoW} processing without electricity
Steel extrusion, initial warming	23.4 kg	23.4 kg	Impact extrusion of steel, hot, initial warming {RoW} processing without electricity
Steel extrusion, hot, tempering	8.97 kg	8.97 kg	Impact extrusion of steel, hot, tempering {RoW} processing without electricity
Aluminum removed by drilling	0.407 kg	0.407 kg	Aluminium removed by drilling, computer numerical controlled {RER} without scrap and electricity
Aluminum removed by drilling	4.58 kg	4.58 kg	Aluminium removed by drilling, computer numerical controlled {RoW} without scrap and electricity

Aluminum removed by milling	4.24 kg	4.24 kg	Aluminium removed by milling, average {RoW} without scrap and electricity
Aluminum removed by turning	0.302 kg	0.302 kg	Cast iron removed by drilling, computer numerical controlled {RER} without scrap and electricity
Cast iron removed by drilling	12 kg	12 kg	Cast iron removed by drilling, computer numerical controlled {RoW} without scrap and electricity
Cast iron removed by milling	33 kg	33 kg	Cast iron removed by milling, average {RoW} without scrap and electricity
Cast iron removed by turning	3.69 kg	3.69 kg	Cast iron removed by turning, average, computer numerical controlled {RoW} without scrap and electricity
Energy and auxiliary inputs	1.67 kg	1.67 kg	Energy and auxilliary inputs, metal working machine {RER} removing electricity
Energy and auxiliary inputs	43.1 kg	43.1 kg	Energy and auxilliary inputs, metal working machine {RoW} removing electricity
Steel removed by drilling	0.699 kg	0.699 kg	Steel removed by drilling, computer numerical controlled {RoW} removing material scrap and electricity
Steel removed by milling	2.3 kg	2.3 kg	Steel removed by milling, average {RoW} removing material scrap and electricity
Steel removed by turning	3.56 kg	3.56 kg	Steel removed by turning, average, computer numerical controlled {RoW} removing material scrap and electricity
PVC coating	0.0328 kg	0.0328 kg	Polyvinylchloride, suspension polymerised {GLO} market for
Transport, freight, lorry	355 tkm	355tkm	Transport, freight, lorry, unspecified {GLO} market for
Transport, freight, sea	3510 tkm	3510 tkm	Transport, freight, sea, container ship {GLO} market for

1.3 H2-ICE conversion

Table S71 H2-ICE conversion

Input from technosphere	H2-ICE reference scenario	
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H2-ICE Conversion Additional Material Needed	1 p	See Table S72
H2-ICE Conversion Manufacturing phase	1 p	See Table S73

Table S72 H2-ICE Conversion Additional Material Needed

Input from technosphere	H2-ICE reference scenario		
H2 Crank Rotating	Flywheel housing	17.33 kg	Cast iron {GLO} market for APOS, U
	Flywheel adapter	65 kg	Steel, low-alloyed {GLO} market for APOS, U
H2 Lube & Vent	Bracket 1	1.02 kg	Aluminium, cast alloy {GLO} market for APOS, U
	Bracket 2	0.51 kg	Aluminium, cast alloy {GLO} market for APOS, U
H2 Air Delivery	Intake manifold dx	2.38 kg	Aluminium, cast alloy {GLO} market for APOS, U
	Intake manifold sx	2.38 kg	Aluminium, cast alloy {GLO} market for APOS, U
H2 Exhaust	PIPE ASM-EXH MANIF OTLT SX	0.8858 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
	PIPE ASM-EXH MANIF OTLT DX	0.8858 kg	Steel, chromium steel 18/8 {GLO} market for APOS, U
Turbo Charging		5.66 kg	Cast iron {GLO} market for APOS, U
		1.448 kg	Chromium steel pipe {GLO} market for APOS, U

Table S73 H2-ICE Conversion Manufacturing phase

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Electricity	1820 MJ	1820 MJ	Low voltage US

1.4 Use phase

Table S74 Use phase

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
WTT	241400 km	241400 km	See Table S75
TTW	241400 km	241400 km	See Table S76
Maintenance	241400 km	241400 km	See Error! Reference source not found.

Table S75 WTT (1 km)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
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Fuel consumption	0.0925 kg	-	Diesel, low-sulfur {GLO} market group for APOS, U
Energy needed	-	3.9036 MJ	Hydrogen-SMR

Table S76 TTW (1 km)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
CO ₂	293.9 g	0	
CO	24.1 g	0	
NO _x	0.52 g	-	Under investigation
PM	0.0064 g	-	Under investigation
HC	0.5028 g	0	

Table S77 Maintenance (1 km)

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
Lubricating oil	167 kg	167 kg	Lubricating oil {RoW} market for lubricating oil APOS, U
Ethylene glycol	32.1 kg	32.1 kg	Ethylene glycol {GLO} market for APOS, U
Fibre polyester	17.5 kg	17.5 kg	Fibre, polyester {GLO} market for fibre, polyester APOS, U
Steel low-alloyed	3.92 kg	11 kg	Steel, low-alloyed {GLO} market for APOS, U
Water	28.7 kg	28.7 kg	Tap water {Europe w/o Switzerland} market for

1.5 EoL phase

Table S78 EoL

Input from technosphere	DIE-ICE	H2-ICE reference scenario	
EoL engine	398 kg	427 kg	Used internal combustion engine, passenger car {GLO} market for used internal combustion engine, passenger car APOS, U