



Life Cycle Assessment - Results

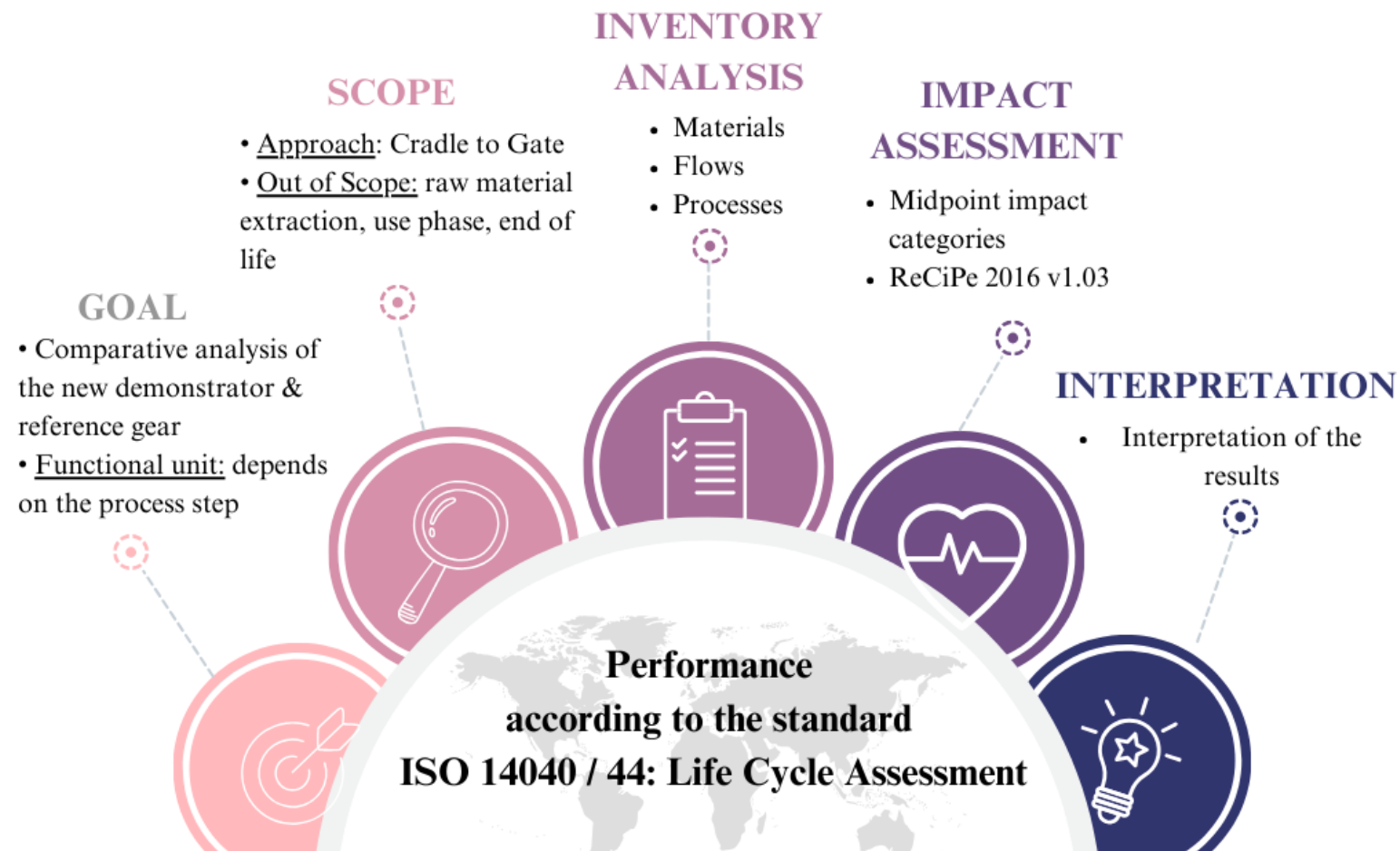
Marcel Egger (i2m)



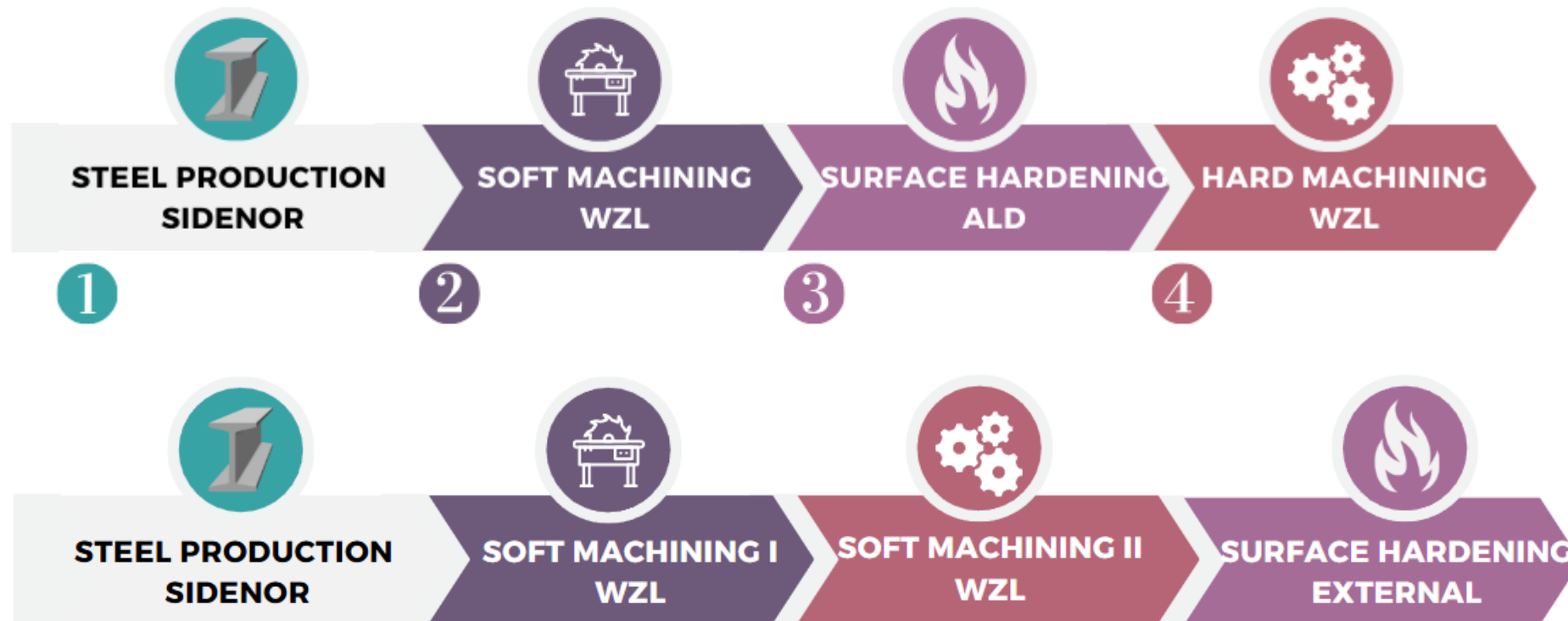
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April 2025, Aachen/ Marcel Egger (i2m)

Life Cycle Assessment (LCA) = systematic assessment of environmental impacts of a product, process, or service (associated with the entire life cycle)



- **Goal:** LCA of traditional and alternative production route for automotive gears
- **Approach:** Cradle to Gate
- **Out of Scope:** Raw Materials, Use Phase, End of Life



LCA approach: Cradle to Gate

Database: Ecoinvent (*ecoinvent v3.10 Cutoff Unit-Processes 2024-06-19*)

Impact Assessment Methode: ReCiPe 2016 v1.03, midpoint



27MnCr5	40CrMoBi4
ELECTRIC ARC FURNACE	ELECTRIC ARC FURNACE
LADLE FURNACE	LADLE FURNACE
CONTINUOUS CASTING	CONTINUOUS CASTING
HOT ROLLING MILL	HOT ROLLING MILL
HEAT TREATMENT	INDUCTION HEATING
FINISHING	FINISHING

LCA Results – Steel Production

GWP - Steel Production				
Processes	27MnCr5	40CrMoBi4	Unit	%
Electric Arc Furnace	63,47	41,09	kg CO2eq	- 35,26
Ladle Furnace	144,52	159,58	kg CO2eq	+ 10,43
Continuous Casting	8,69	8,69	kg CO2eq	0,00
Hot Rolling	132,74	132,74	kg CO2eq	0,00
Heat Treatment - Q&T	148,12	15,92	kg CO2eq	- 89,25
Auxiliary Services	2,66	2,66	kg CO2eq	+ 0,01
Finishing	0,07	0,12	kg CO2eq	+ 62,98
Total	500,26	360,80	kg CO2eq	- 27,88

27MnCr5:

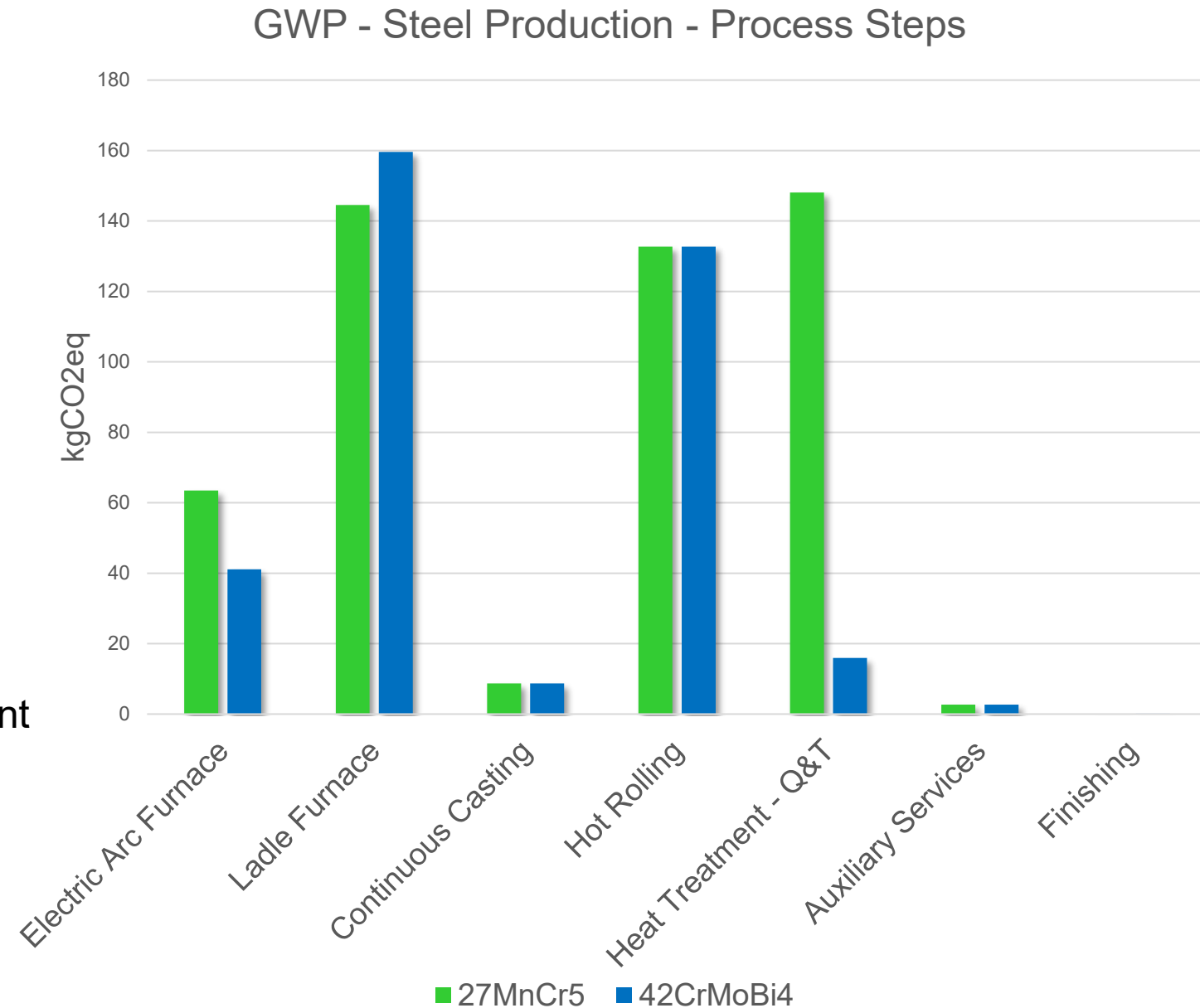
- Highest GWP 27MnCr5: Ladle Furnace & Heat Treatment

40CrMoBi4:

- Highest GWP 40CrMoBi4: Ladle Furnace & Hot Rolling

➔ GWP Comparison Steel Production:

~ 140 kgCO2eq / 1t steel less Emissions



LCA approach: Cradle to Gate

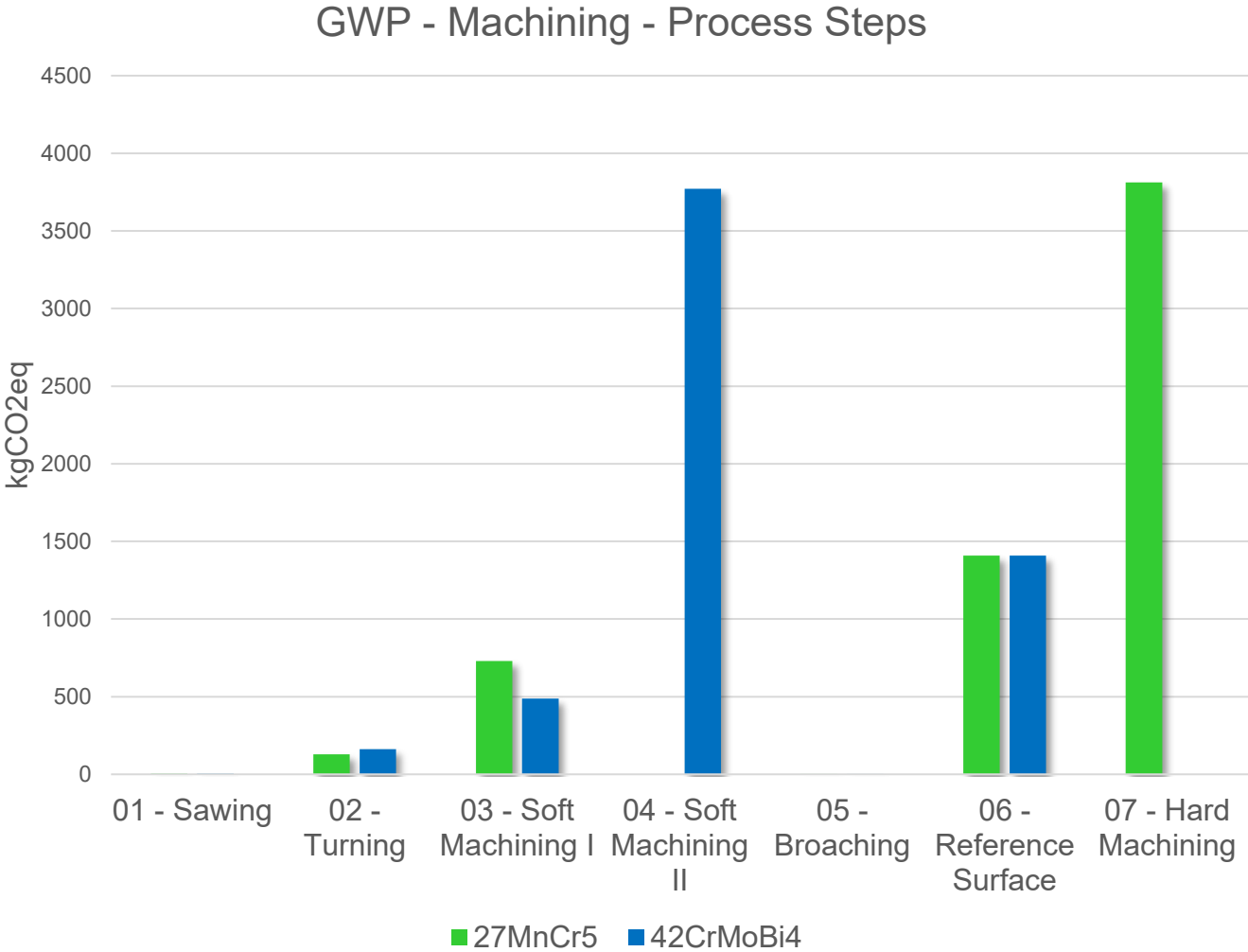
Database: Ecoinvent (*ecoinvent v3.10 Cutoff Unit-Processes*
2024-06-19)

Impact Assessment Methode: ReCiPe 2016 v1.03, midpoint



27MnCr5	40CrMoBi4
SAWING	SAWING
TURNING	TURNING
SOFT MACHINING	SOFT MACHINING I
BROACHING	BROACHING
HEAT TREATMENT	REFERENCE SURFACE
REFERENCE SURFACE	SOFT MACHINING II
HARD MACHINING	NITRIDING
QUALITY CONTROL	QUALITY CONTROL

GWP – Machining – 600 Gears				
Impact Category	27MnCr5	42CrMoBi4	Unit	%
01 - Sawing	2,964	3,705	kg CO2eq	+ 24,98
02 - Turning	129,22	161,47	kg CO2eq	+ 24,95
03 - Soft Machining I	730,55	487,27	kg CO2eq	- 33,30
04 - Soft Machining II	-	3771,56	kg CO2eq	-
05 - Broaching	1,990	2,487	kg CO2eq	+ 24,97
06 - Reference Surface	1409,26	1409,26	kg CO2eq	0,00
07 - Hard Machining	3812,17	-	kg CO2eq	-
Total	6086,15	5835,75	kg CO2eq	- 4,11

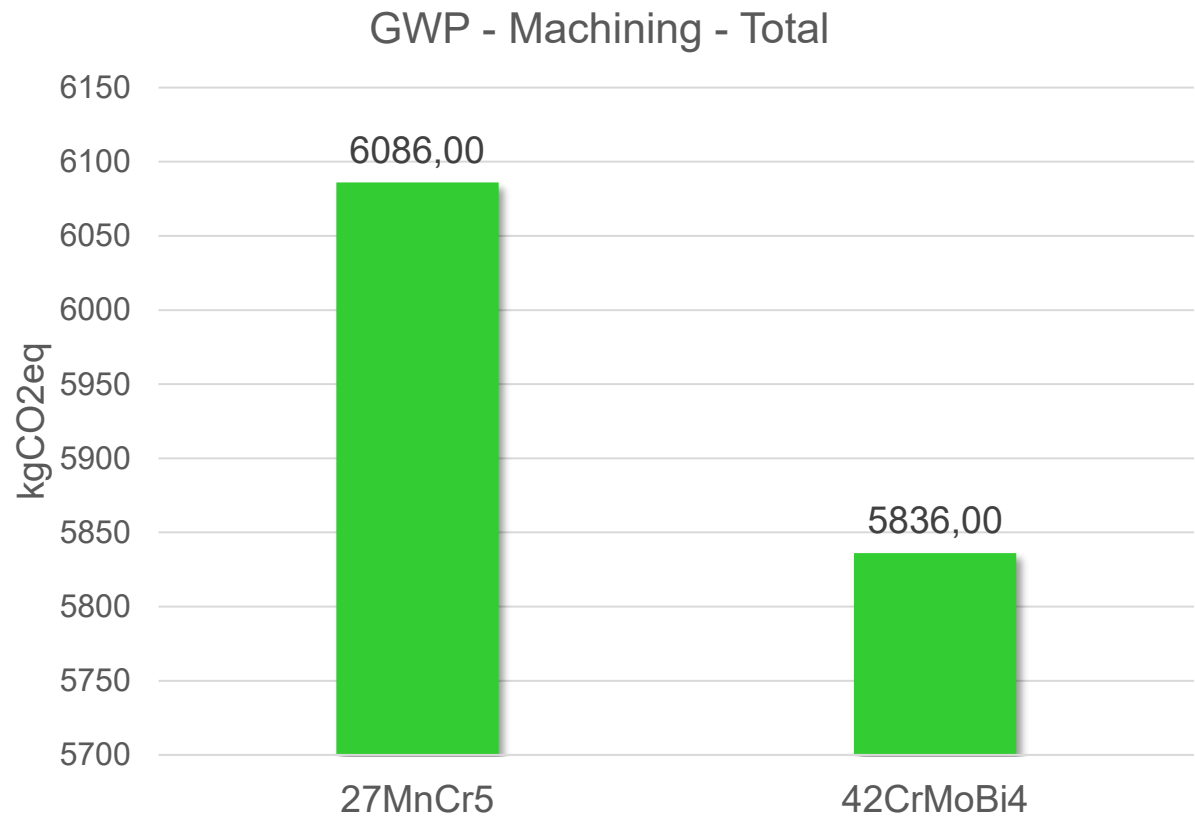


27MnCr5:

- Highest GWP 27MnCr5: Hard Machining

40CrMoBi4:

- Highest GWP 40CrMoBi4: Soft Machining II



GWP – Machining – 600 Gears				
Impact Category	27MnCr5	42CrMoBi4	Unit	%
Total	6086,15	5835,75	kg CO2eq	- 4,11

27MnCr5:

- For 600 Gears

40CrMoBi4:

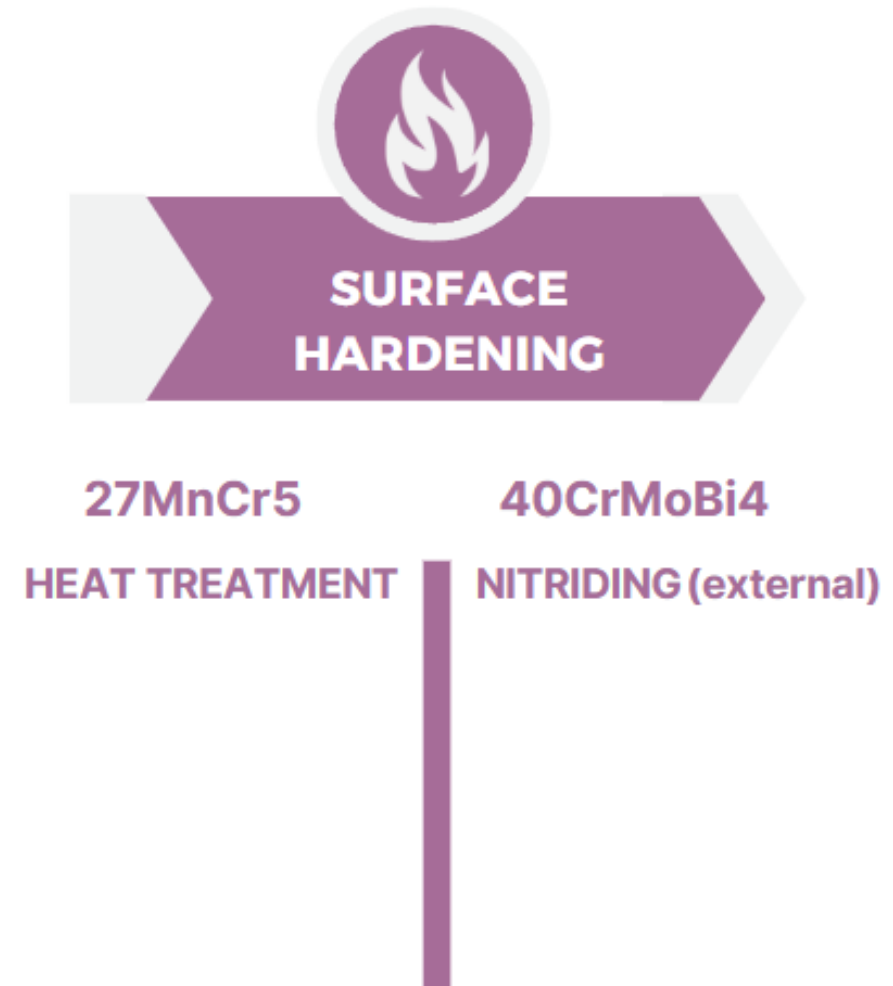
- For 600 Gears

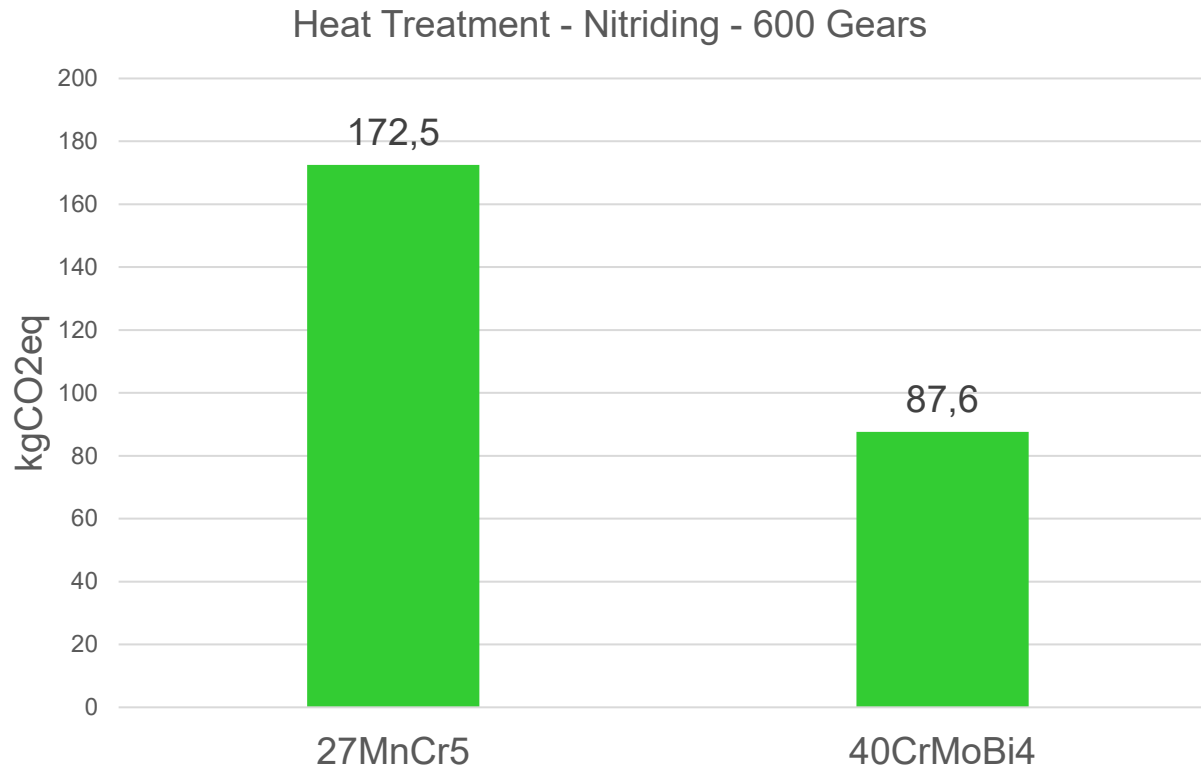
➔ **GWP Comparison Machining:**
~ 250 kgCO₂eq

LCA approach: Cradle to Gate

Database: Ecoinvent (*ecoinvent v3.10 Cutoff Unit-Processes*
2024-06-19)

Impact Assessment Methode: ReCiPe 2016 v1.03, midpoint





27MnCr5:

- Heat Treatment (400 gears)

40CrMoBi4:

- Nitriding (1540 gears)

Limitations:

- Comparison
 - Charge ALD max. ~ 400 gears
 - Charge External max. ~ 1540 gears
- Gearbox has different gear sizes

GWP - Surface Hardening – 1 Batch			
Process	27MnCr5	40CrMoBi4	Unit
Heat Treatment - Nitriding	115	226	kg CO ₂ eq

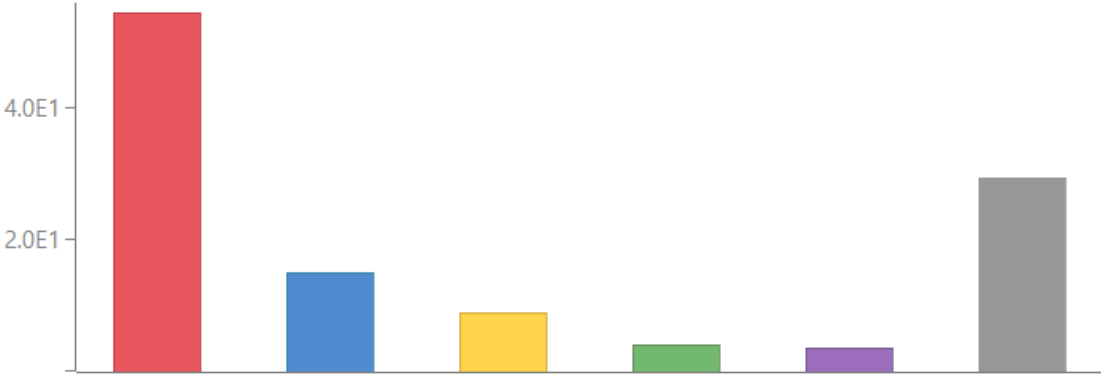
GWP - Surface Hardening – 1 Gear			
Process	27MnCr5	40CrMoBi4	Unit
Heat Treatment - Nitriding	0,2875	0,146	kg CO ₂ eq

➔ GWP Comparison Surface Hardening:

~ 85 kgCO₂eq less Emissions for 600 gears

27MnCr5:

- Heat Treatment (400 gears)



54.331 kg CO2-Eq: electricity production, lignite | electricity, high voltage | Cutoff, U - DE

14.881 kg CO2-Eq: electricity production, hard coal | electricity, high voltage | Cutoff, U - DE

8.892 kg CO2-Eq: heat and power co-generation, natural gas, conventional power plant, 100MW electrical | electricity, high voltage | Cutoff, U - DE

4.065 kg CO2-Eq: heat and power co-generation, hard coal | electricity, high voltage | Cutoff, U - DE

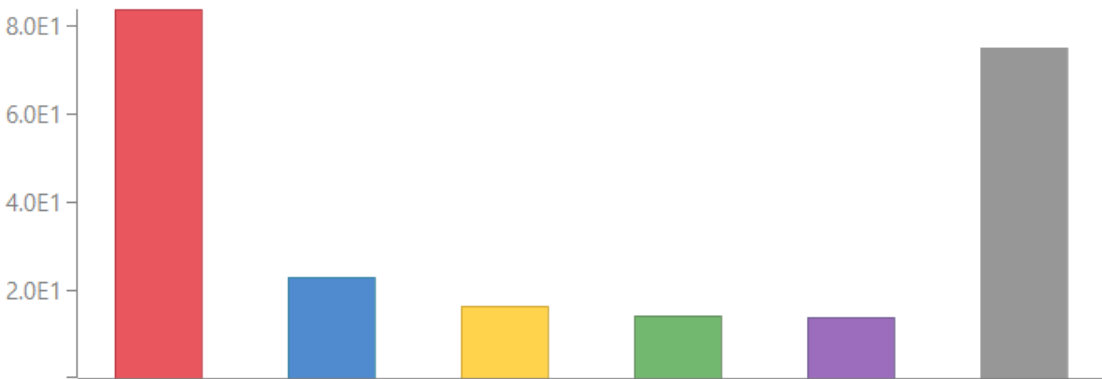
3.590 kg CO2-Eq: electricity production, natural gas, conventional power plant | electricity, high voltage | Cutoff, U - DE

29.239 kg CO2-Eq: Other

Contribution Tree - GWP			
Process	27MnCr5	Unit	Contribution
Electricity	105,33	kg CO2eq	91,60%
Nitrogen	8,89	kg CO2eq	7,73%
Acetylen	0,77	kg CO2eq	0,67%
Total	114, 99	kg CO2eq	100%

40CrMoBi4:

- Nitriding (1540 gears)



- 83.824 kg CO2-Eq: electricity production, lignite | electricity, high voltage | Cutoff, U - DE
- 22.959 kg CO2-Eq: electricity production, hard coal | electricity, high voltage | Cutoff, U - DE
- 16.175 kg CO2-Eq: ammonia production, steam reforming, liquid | ammonia, anhydrous, liquid | Cutoff, U - RER w/o RU
- 14.089 kg CO2-Eq: ammonia production, steam reforming, liquid | ammonia, anhydrous, liquid | Cutoff, U - RU
- 13.719 kg CO2-Eq: heat and power co-generation, natural gas, conventional power plant, 100MW electrical | electricity, high voltage | Cutoff, U - DE
- 75.063 kg CO2-Eq: Other

Contribution Tree - GWP			
Process	40CrMoBi4	Unit	Contribution
Electricity	164,21	kg CO2eq	72,72%
Nitrogen	55,79	kg CO2eq	24,71%
Ammonia	5,82	kg CO2eq	2,58%
Total	225,83	kg CO2eq	100%

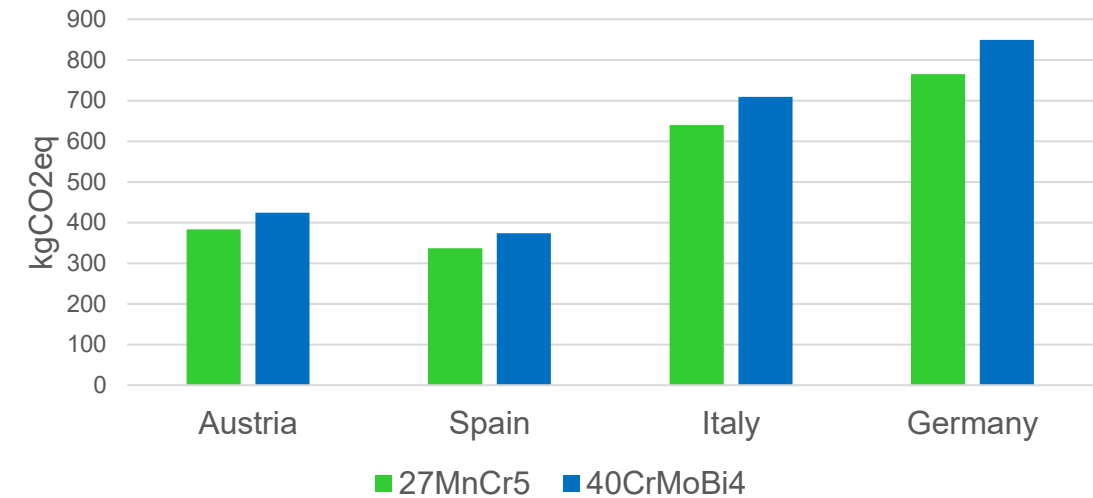
Energy Comparison

- Energy comparison between the partner countries
- Spain has the lowest GWP, Germany the highest

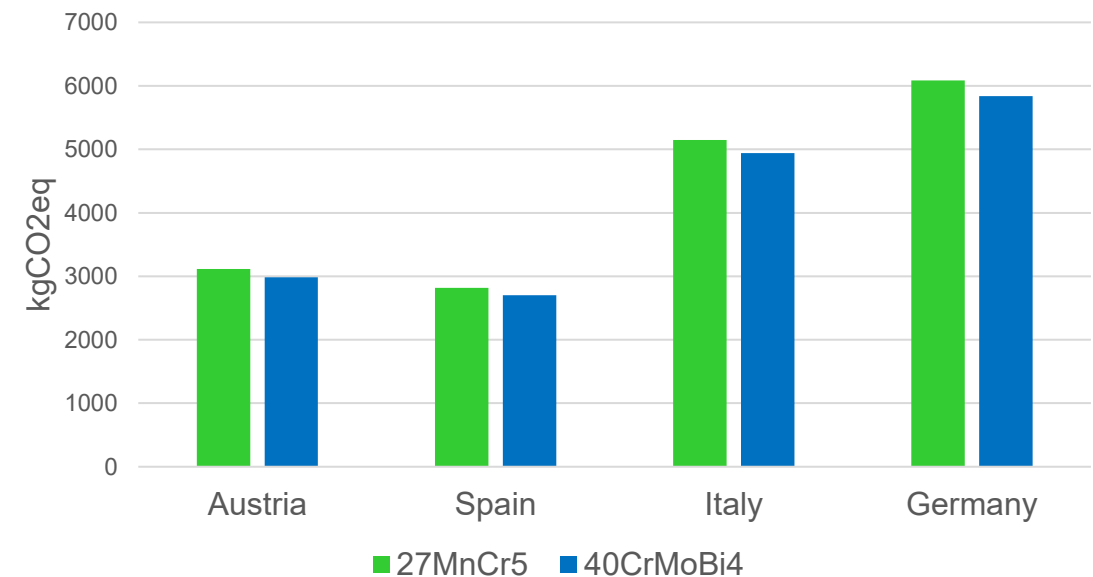
GWP - Energy Comparison Countries - Steel Production			
Impact Category	27MnCr5	40CrMoBi4	Unit
Austria	383	424	kg CO2eq
Spain	337	374	kg CO2eq
Italy	640	709	kg CO2eq
Germany	765	849	kg CO2eq

GWP - Energy Comparison Countries - Machining			
Impact Category	27MnCr5	40CrMoBi4	Unit
Austria	3113	2985	kg CO2eq
Spain	2819	2703	kg CO2eq
Italy	5149	4938	kg CO2eq
Germany	6086	5836	kg CO2eq

Energy Comparison - Steel Production

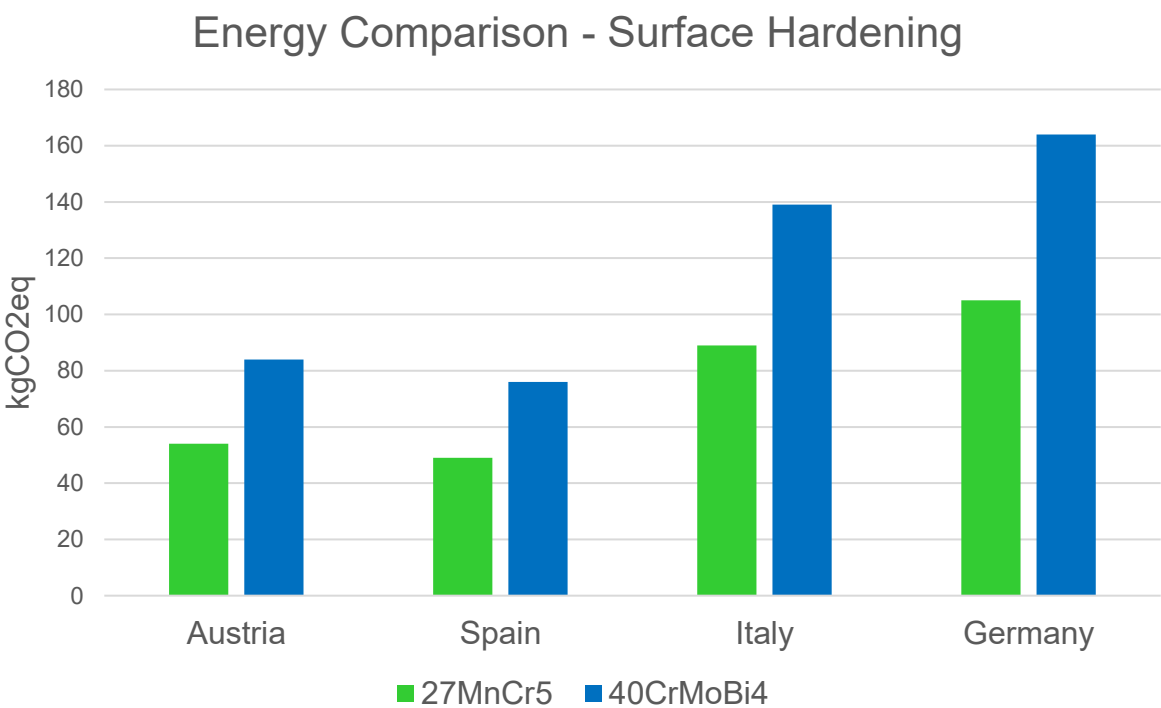


Energy Comparison - Machining



- ➔ Energy comparison between the partner countries
- ➔ Spain has the lowest GWP, Germany the highest

GWP - Energy Comparison Countries - Surface Hardening			
Impact Category	27MnCr5	40CrMoBi4	Unit
Austria	54	84	kg CO2eq
Spain	49	76	kg CO2eq
Italy	89	139	kg CO2eq
Germany	105	164	kg CO2eq



→ GWP Comparison Steel Production:

~ 40CrMoBi **140 kgCO₂eq / 1t steel** less Emissions than 27MnCr5

- 27% reduction

→ GWP Comparison Machining:

~ 40CrMoBi **250 kgCO₂eq / 600 gears** less Emissions than 27MnCr5

- 4% reduction

→ GWP Comparison Surface Hardening:

~ 40CrMoBi **84,9 kgCO₂eq / 600 gears** less Emissions than 27MnCr5

- 49% reduction (limitation)

→ Energy Comparison:

Spain has the lowest GWP, followed by Austria and Italy, Germany the highest

Thank you for your attention!

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