Environmental Life Cycle Assessment of Electric and Conventional Vehicles: A Case Study of Lithuania from 2015 to 2050

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Global issues

- **Air pollution caused by road transport**

(CO, NMVOC, NOx, NH_3, $PM_{2.5}$)

- **Climate change**

(increase of greenhouse gas emissions)

- **Noise**

(noise from road traffic is the second most harmful environmental stressor in Europe after air pollution)

(*Source: EEA*)

Motivation at European level

2020 climate & energy package

- At least 20 **%** cut in **greenhouse gas** emissions (from 1990 levels)
- At least 20 % share for **renewable energy**
- At least 20 % improvement in **energy efficiency**

2030 climate & energy framework

- At least 40 % cut in **greenhouse gas emissions** (from 1990 levels)
- At least 32 % share for **renewable energy**
- At least 32.5 % improvement in **energy efficiency**

2050 long-term strategy

- prosperous, modern, competitive and **climate neutral economy by 2050** – A Clean Planet for all.

(Source: European Commission)

Motivation at Lithuanian level

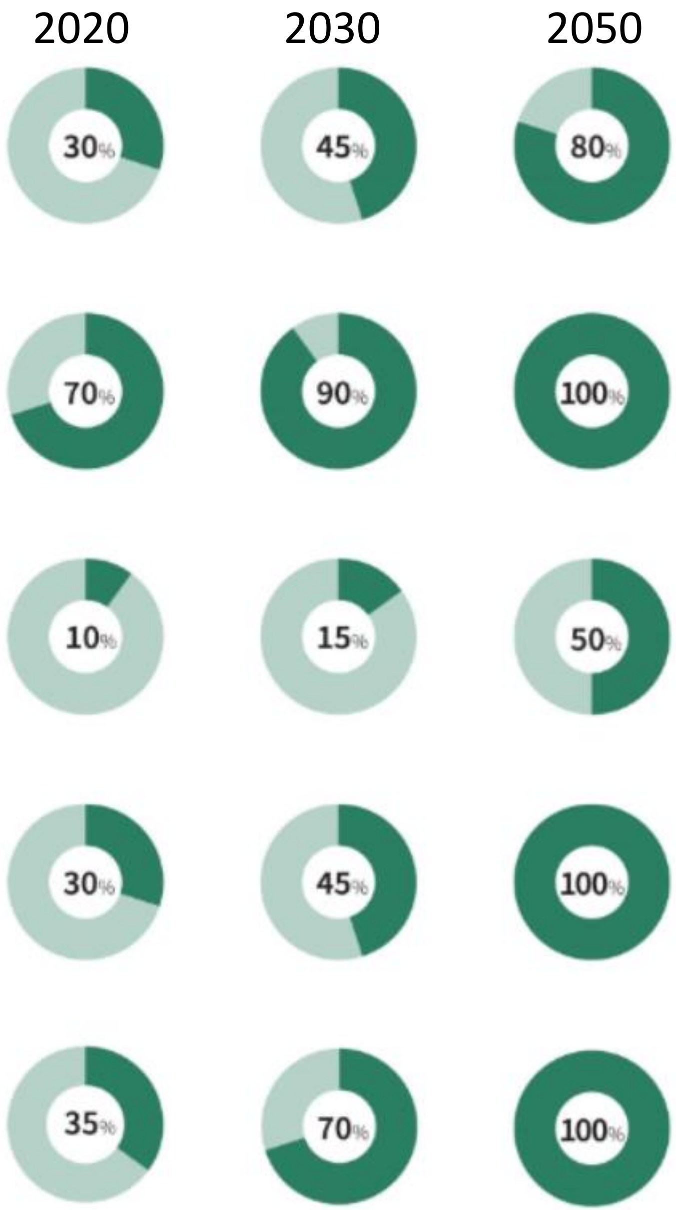
The share of renewable energy resources (RES) in the final energy consumption balance

The share of RES and local resources in district heating sector

The share of RES in the transport sector

The share of RES in the electricity consumption balance

Electricity production in Lithuania

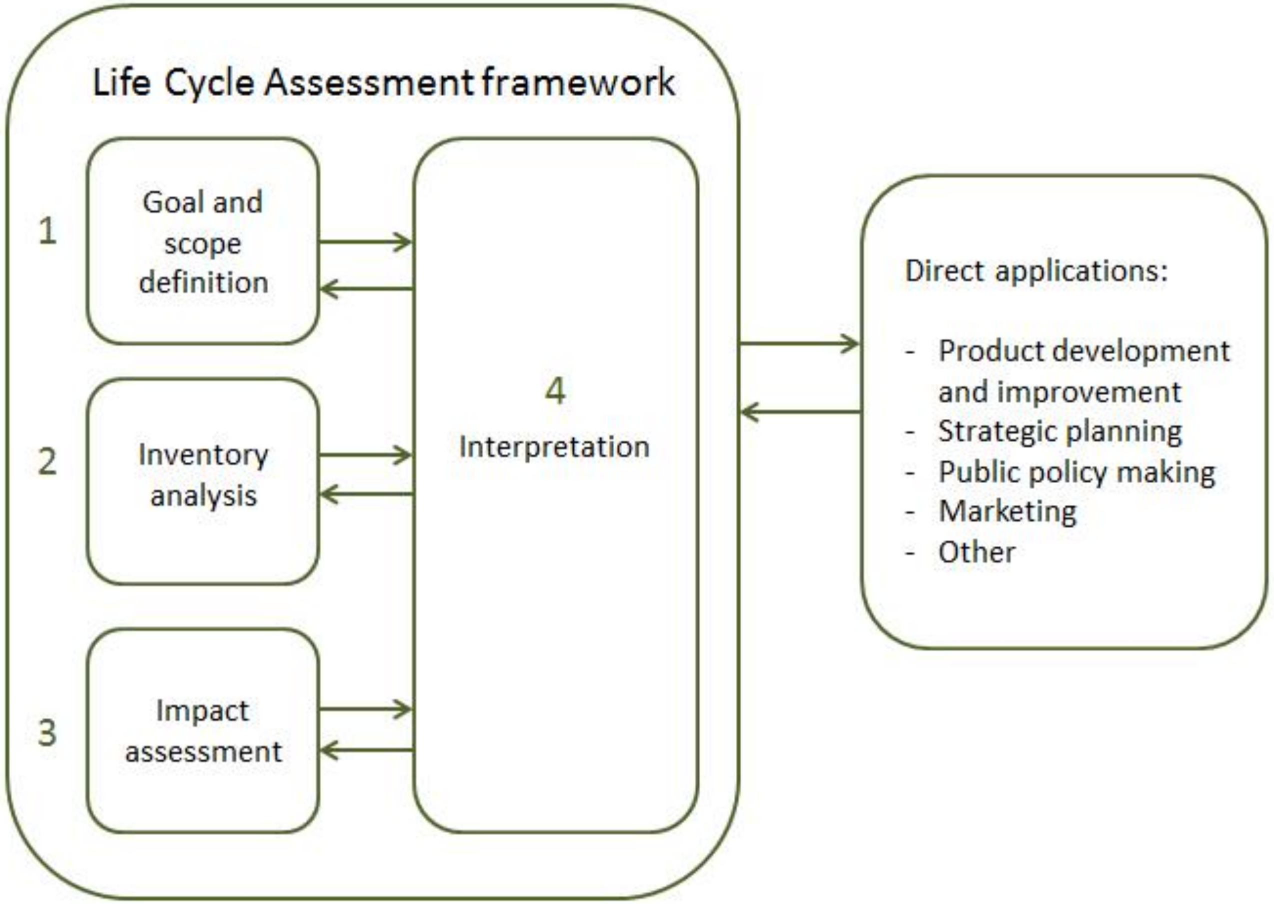


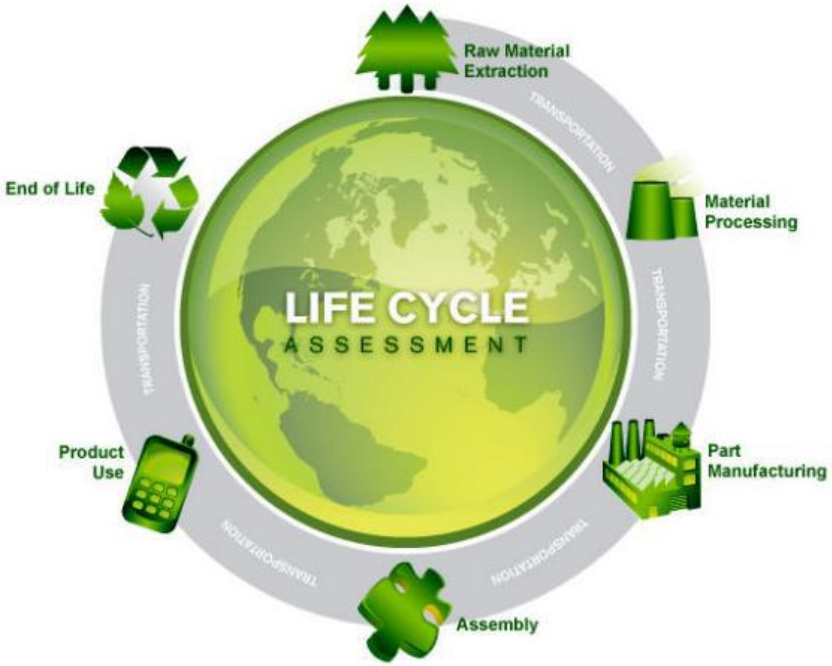
(Source: Ministry of Energy of the Republic of Lithuania, 2018)

Aim of the study

- To evaluate and compare the environmental impacts of battery electric vehicle (BEV) and internal combustion engine vehicles (ICEVs) fuelled with diesel and petrol;
- To analyse the BEV’s operation stage under different electricity generation scenarios that are forecasted for the years 2015–2050 in Lithuanian context;
- To assess the most preferable electricity mix scenario and generation technologies under which the environmental load would be the least.

Methodology

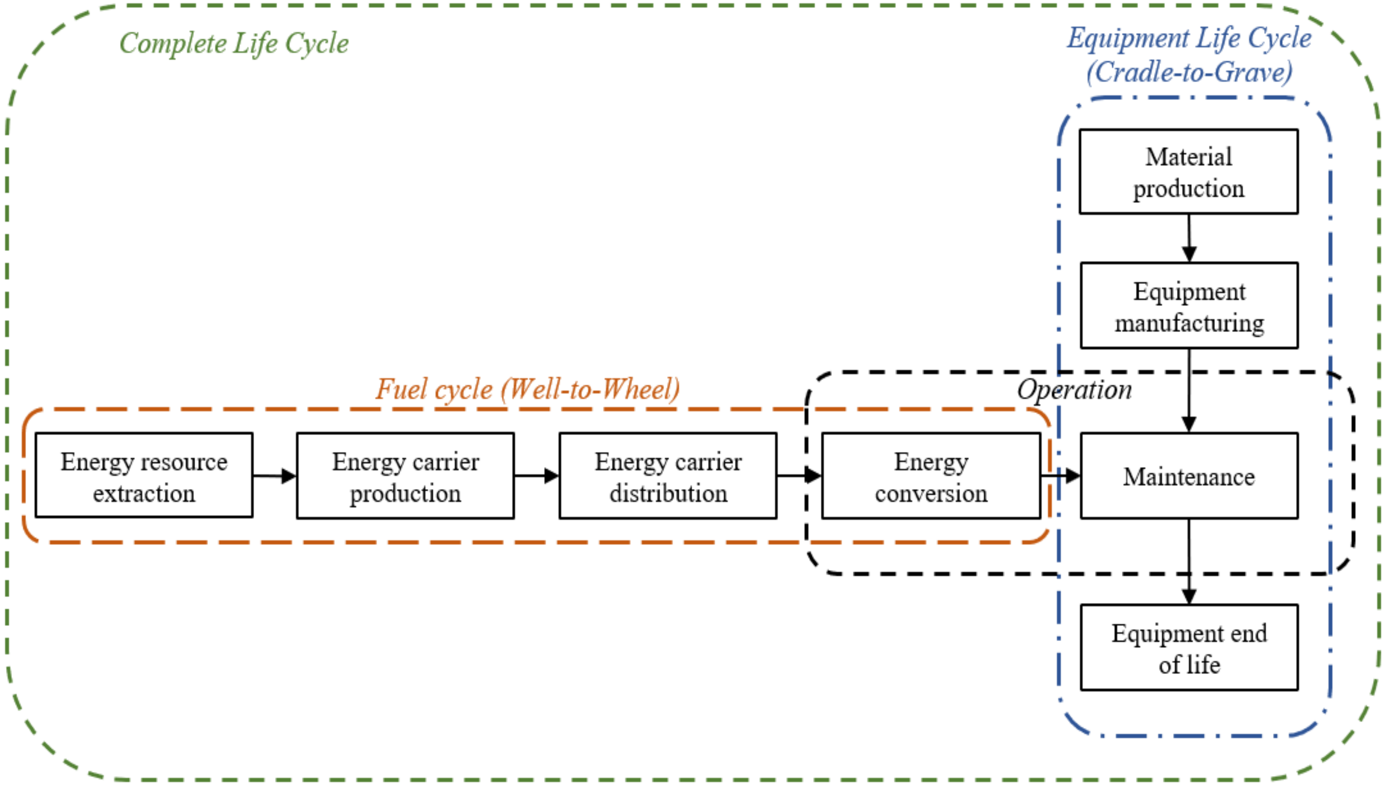




(Source: ISO 14040:2006, 2006)

Scope of the study (1)

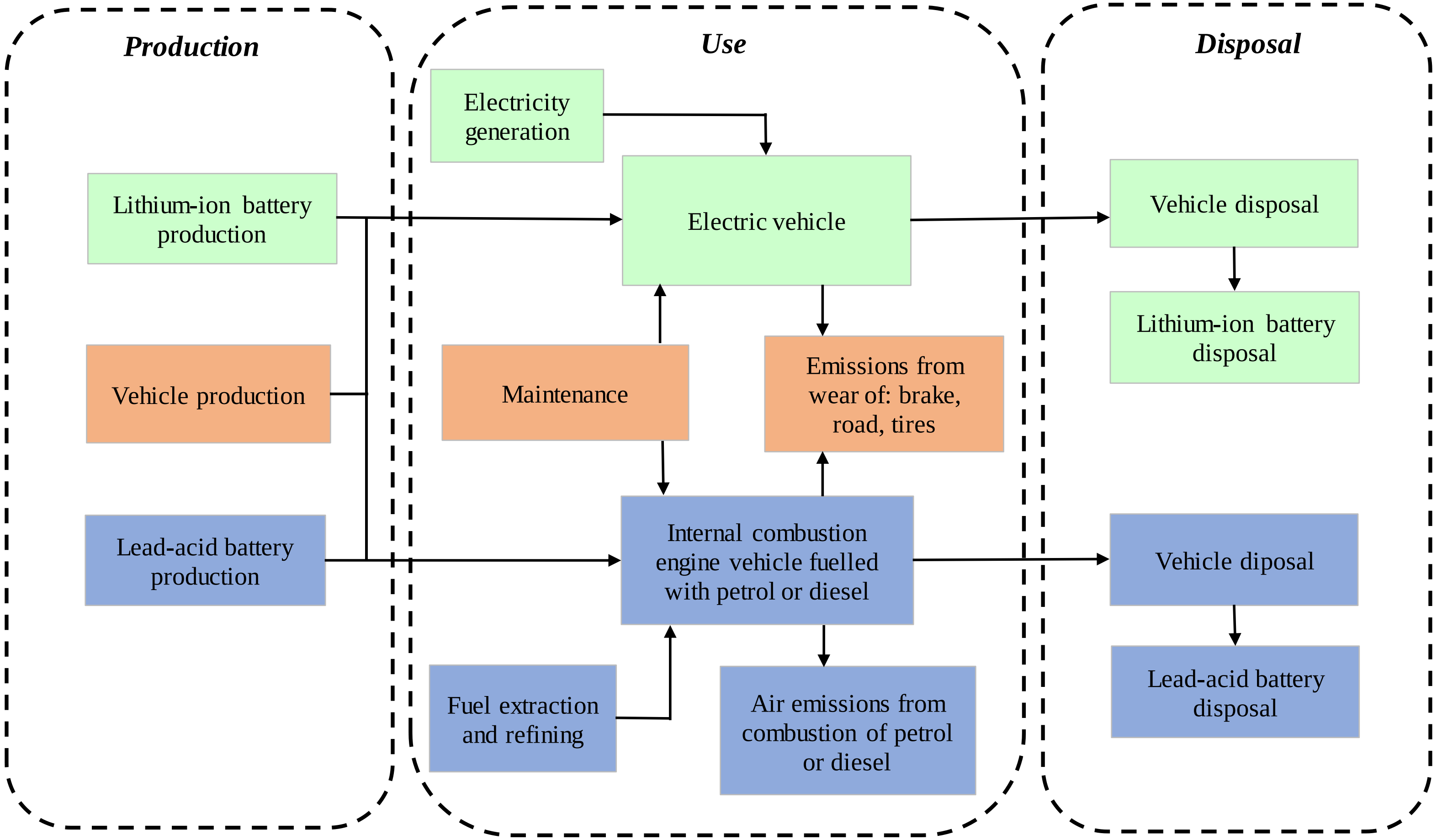
The scope of this analysis represents a “complete LCA”, which includes the fuel cycle as “Well-To-Wheel” analysis and the vehicle life cycle that follows a “Cradle-to-Grave” approach



(Source: adapted from Nordelof et al., 2014)

Scope of the study (2)

The results of the LCA are presented in three combined phases: production, use and disposal



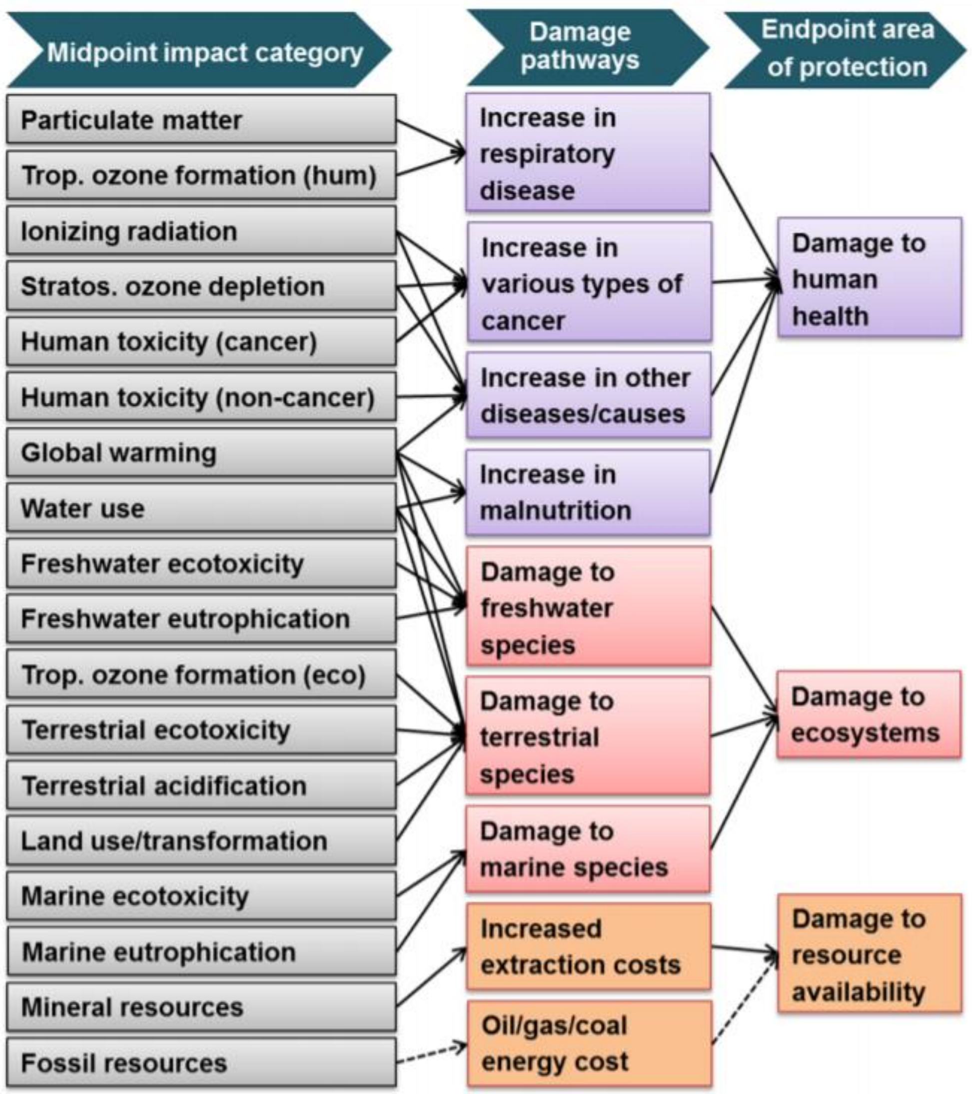
(Source: adapted from Burchart-Korol et al., 2018)

Life cycle impact assessment method

- the **ReCiPe** method at the <u>midpoint</u> and <u>endpoint</u> levels was used to perform the impact assessment
- database Ecoinvent 3
- SimaPro software

ecoinvent

SimaPro



(Source: National Institute for Public Health and the Environment, 2017)

Inventory analysis (1)

Functional unit – 1 km driven distance

Fiat Tipo (2018)

Technical specifications of Fiat Tipo:
Height – 1495 mm
Length – 4265 mm
Weight – 1395 kg
Fuel consumption (combined):
– 6,5 l/100km (petrol)
– 4,6 l/100km (diesel)

(Source: JSC "Autobrava Motors", 2019)

Nissan Leaf (2018)

Technical specifications of Nissan Leaf:
Height – 1530 mm
Length – 4490 mm
Battery capacity – 40 kWh
Battery – 296 kg
Weight without battery – 1249 kg
Vehicle energy consumption – 20,6 kWh/100km

(Source: Electric Vehicle Database, 2019)

Inventory analysis (2)

Proportions of electricity production in the energy system by source in Lithuania (2015–2050)

Unit, %	2015	2020	2025	2030	2035	2040	2045	2050
Waste	2.28	6.63	4.16	2.50	2.50	1.79	1.79	1.28
Biogas	3.51	4.79	1.75	0.57	0.57	0.97	0.97	1.13
Biomass	5.85	24.12	25.18	15.56	15.56	4.97	4.97	4.49
Natural gas	41.73	10.33	10.67	11.09	11.09	19.90	19.90	7.28
Hydro	20.55	6.97	5.28	4.44	4.44	6.34	6.34	5.72
Wind	14.56	36.76	38.58	52.40	52.40	34.86	34.86	33.61
Solar	1.76	5.96	11.71	11.83	11.83	30.00	30.00	45.57
Geothermal	5.19	4.45	2.68	1.60	1.60	1.17	1.17	0.93
Oil	4.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(Source: Lithuanian Energy Institute, 2017)

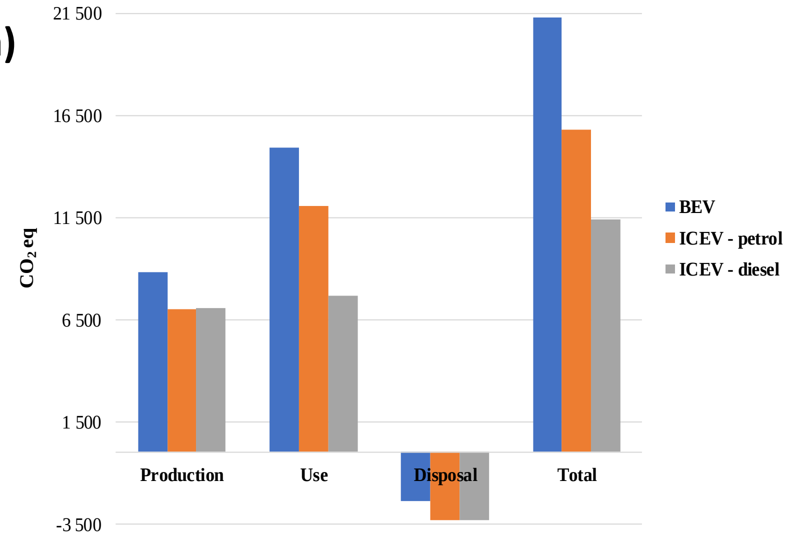
Results of the LCA at the midpoint level (1)

Results of full LCA of ICEVs powered with petrol and diesel and BEV under prognosticated energy mix scenarios 2015–2050 in Lithuania

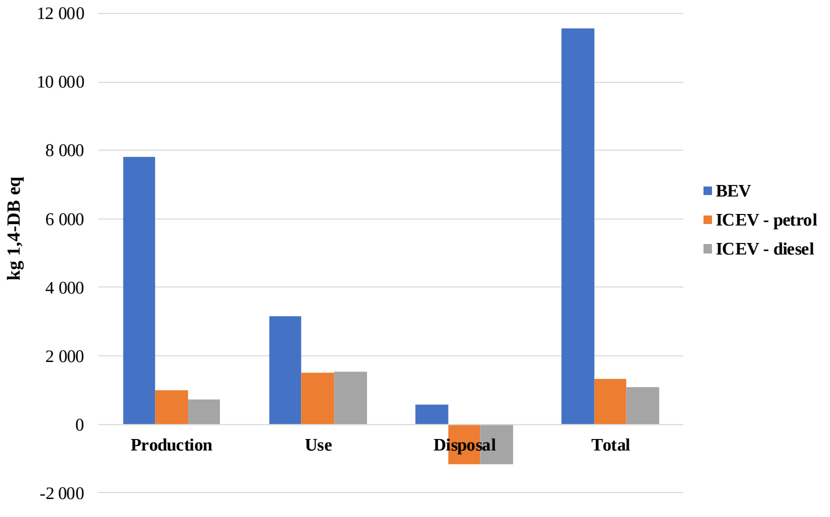
Impact category	ICEV - petrol	ICEV - diesel	BEV 2015	BEV 2020	BEV 2025	BEV 2030	BEV 2035	BEV 2040	BEV 2045	BEV 2050	Total
Climate change	15 787	11 394	21 304	10 247	10 021	10 688	10 688	13 758	13 758	11 719	**129 363**
Ozone depletion	0	0	0	0	0	0	0	0	0	0	0
Terrestrial acidification	536	523	-416	-456	-458	-457	-457	-454	-454	-459	-2 552
Freshwater eutrophication	3	3	5	3	3	4	4	6	6	6	42
Marine eutrophication	1	1	5	10	9	6	6	3	3	3	46
Human toxicity	1 325	1 095	11 555	15 369	15 015	12 682	12 682	10 808	10 808	10 975	**102 313**
Photochemical oxidant formation	96	83	40	63	57	30	30	9	9	6	422
Particulate matter formation	124	117	-70	-100	-100	-88	-88	-75	-75	-75	-429
Terrestrial ecotoxicity	5	4	6	6	6	6	6	7	7	7	60
Freshwater ecotoxicity	71	66	87	103	101	90	90	81	81	81	852
Marine ecotoxicity	6	-2	76	86	87	79	79	82	82	90	666
Ionising radiation	1 973	1 711	202	-752	-706	-337	-337	51	51	21	**1 877**
Agricultural land occupation	8 969	3 797	-13 986	-40 675	-37 866	-22 678	-22 678	-8 521	-8 521	-8 046	-150 206
Urban land occupation	254	195	1	-5	-7	-6	-6	-3	-3	0	421
Natural land transformation	13	10	4	-1	-1	0	0	1	1	1	28
Water depletion	376	225	-219	-834	-769	-431	-431	-95	-95	-75	-2 348
Metal depletion	-5 424	-5 760	3 804	5 045	4 964	4 264	4 264	3 743	3 743	3 866	**22 507**
Fossil depletion	13 669	10 498	6 136	687	822	1 898	1 898	3 720	3 720	2 910	**45 957**

Results of the LCA at the midpoint level (2)

a)



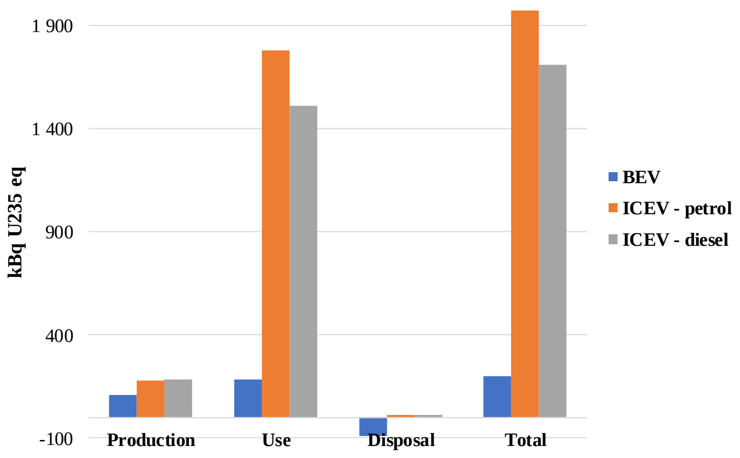
b)



BEV (electricity mix of 2015) and ICEVs assessment of these environmental indicators:

a) climate change
b) human toxicity
c) ionizing radiation
d) metal depletion
e) fossil depletion

c)



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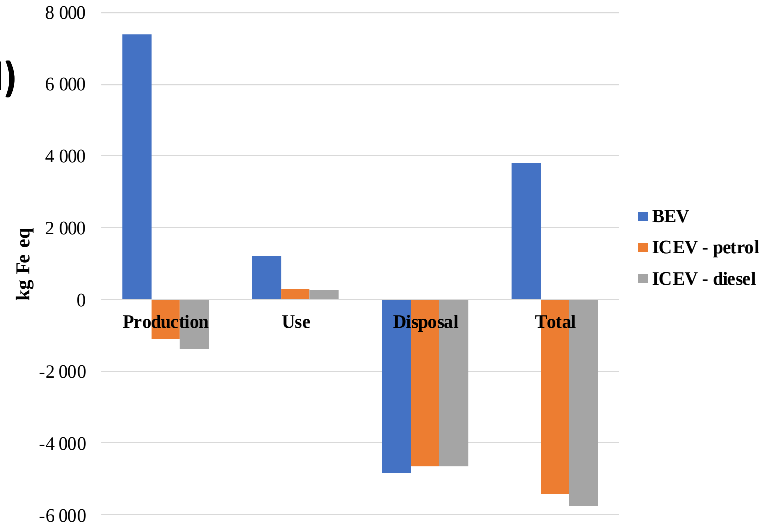
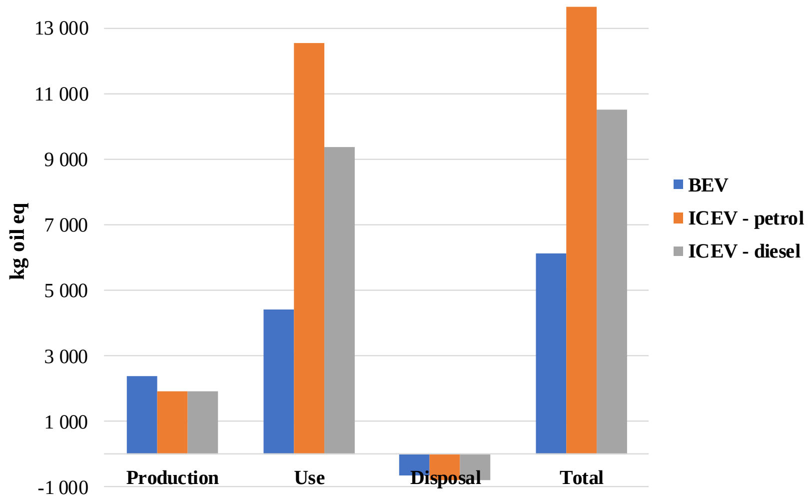
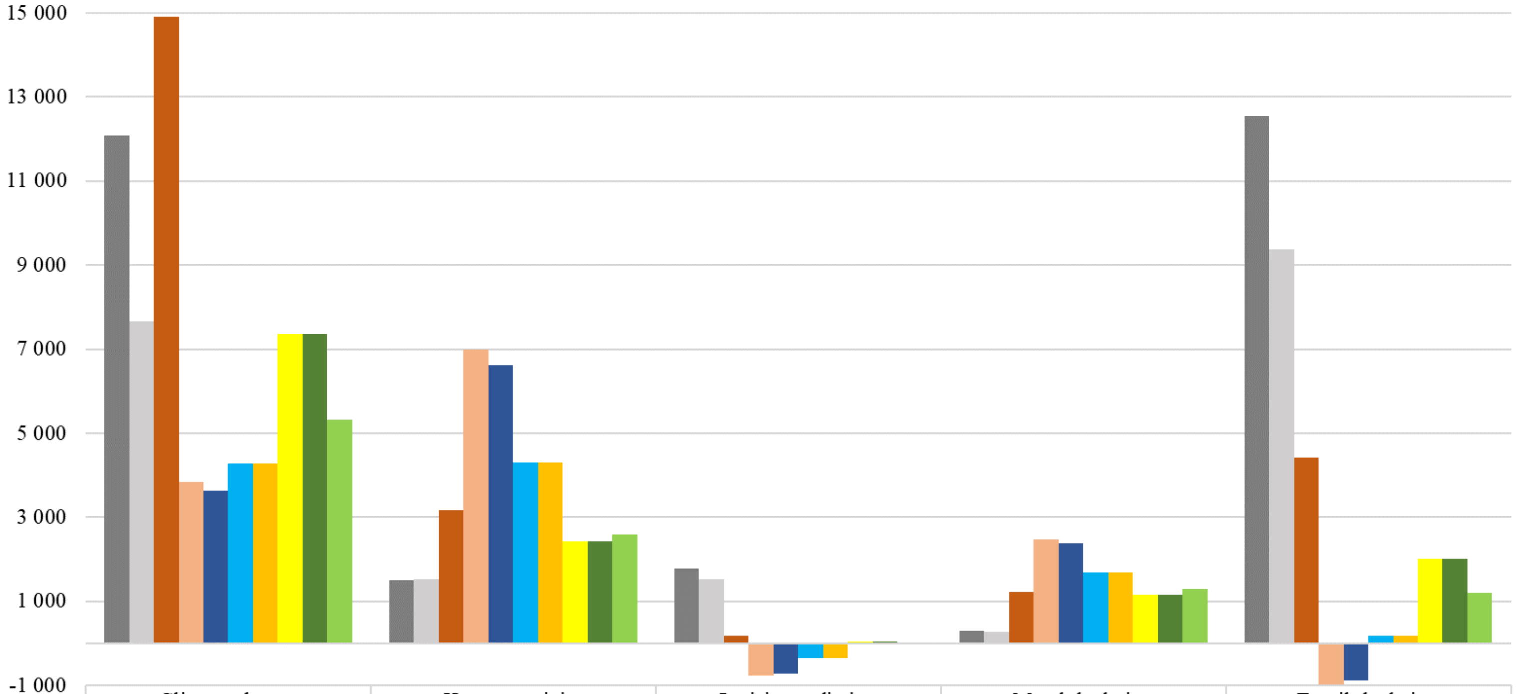


e)



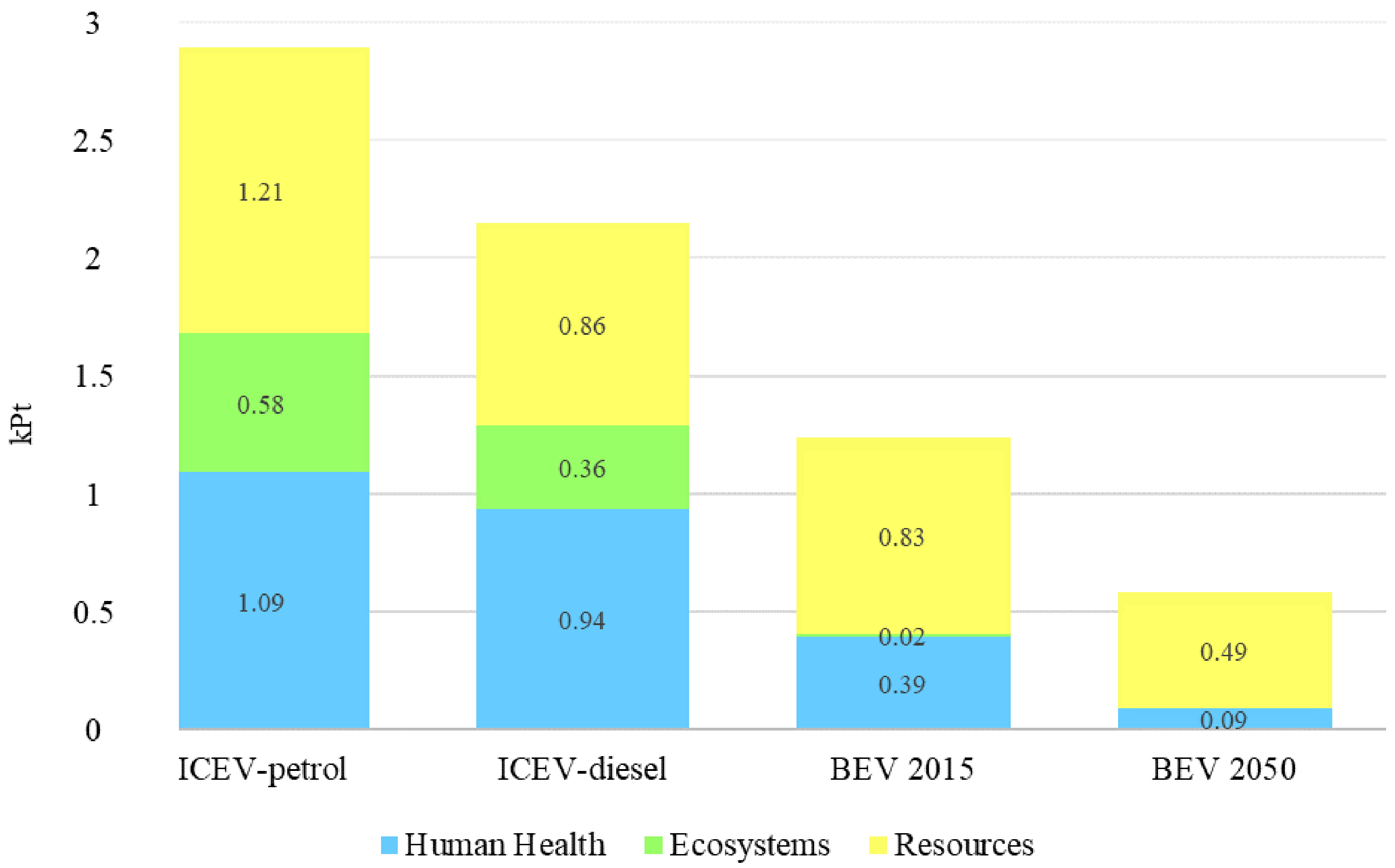
Results of the LCA at the midpoint level (3)

Results of the use phase of ICEVs and battery electric vehicle (electricity mix of 2015–2050)



	Climate change	Human toxicity	Ionising radiation	Metal depletion	Fossil depletion
ICEV - petrol	12 077	1 501	1 782	299	12 544
ICEV - diesel	7 669	1 526	1 515	268	9 370
BEV, 2015	14 907	3 165	185	1 224	4 420
BEV, 2020	3 850	6 979	-770	2 465	-1 029
BEV, 2025	3 624	6 625	-723	2 384	-893
BEV, 2030	4 291	4 292	-354	1 683	183
BEV, 2035	4 291	4 292	-354	1 683	183
BEV, 2040	7 361	2 418	33	1 163	2 004
BEV, 2045	7 361	2 418	33	1 163	2 004
BEV, 2050	5 322	2 585	4	1 286	1 195

LCA results of BEV (electricity mix of 2015 and 2050) and comparison with ICEVs at the endpoint level



Conclusions (1)

1. LCA at the midpoint level showed that throughout the whole life cycle BEV of 2015 electricity mix is advantaged in ionizing radiation and fossil depletion, while both ICEVs had lower impact in climate change, human toxicity and metal depletion.

2. The BEV impact on climate change is 26 and 47 % bigger than that of ICEVs fuelled with petrol and diesel, respectively. This is because the BEV’s operation phase amounts to 70 % of the total burden, where electricity (used to recharge the battery) of 2015 was produced with natural gases (41.7 %) and oil (5 %), which will be eliminated for the later scenarios.

3. Furthermore, human toxicity of BEV is the highest in all energy mix scenarios, and this indicator is associated with the production of an electric car and Li-ion battery, accounting for 36 and 31 % of the total impact, respectively. Besides, it was identified that GHG emissions of BEV would be lower than those for ICEVs in the 2020, 2025, 2030 and 2035 scenarios. This is because wind energy and biomass are the main sources in electricity production and the use of natural gases is decreased approximately 4 times for these years.

4. Next, BEV in the 2050 scenario has one of the lowest values in almost all the categories comparing to the 2015 scenario. The use phase of BEV (2050 electricity mix) will emit 31 and 56 % less GHG emissions than ICEV-diesel and ICEV-petrol, respectively. This is because the electricity mix of 2050 consists of the main sources – solar (45.6 %) and wind energy (33.6 %).

Conclusions (2)

5. At the endpoint level, the results showed that ICEV fuelled with petrol has a major impact in damage assessment, where the impact on human health (38 %) and resources (42 %) contribute the most. Next, ICEV fuelled with diesel follow with 28 % less total environmental damage, where both impacts on human health and resources contribute equally and the least impact belongs to ecosystems.

6. Moreover, the results showed that BEV of 2015 electricity mix has almost zero damage for ecosystems and the total impact is 42 and 57 % less than ICEV-diesel and ICEV-petrol, respectively. Furthermore, it is assessed that the “environmental damage” of BEV with electricity mix of 2050 is 54 % smaller than that of BEV with electricity mix of 2015, and 73 and 80 % less than ICEVs fuelled with diesel and petrol, respectively.

Thank you for your attention!

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