

ライフサイクルアセスメント  
生命週期評估  
전 과정 평가  
வாழ்க்கை வட்டப் பகுப்பாய்வு  
ارزیابی چرخه عمر  
Evaluarea Ciclului de Viață  
Posuzování Životního Cyklu  
Bizi zikloaren analisi  
Olelusingi hindamine  
Lífsferilsgreining  
Levenscyclusanalyse  
Livscyklusvurdering

Developing LCI background data for oil and gas  
over a period of 30 years

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# Developing LCI background data for oil and gas over a period of 30 years

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Imperial College  
Online Workshop  
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## We provide...

- Consulting
  - Case studies on LCAs, OLCA, CF, EPD & PEF (compliant with different standards)
- Tools
  - LCA software, automation, key parameter models
  - Databases and single datasets (data-on-demand)
- Expertise
  - Training & coaching
  - Critical peer reviews, verification & validation

## LCI projects for oil and gas extraction

- *Ökoinventare von Energiesystemen (1994, 1996)*
- LCA of kerosene and LPG in India (1994-1996)
- Erdöl und Erdgas (ecoinvent 2000 in 2003 and small update 2007)
- LCI oil products (FOEN, BFE, Erdölvereinigung, 2018) incl. refinery, distribution and oil heating
- LCI oil and gas supply (FOEN & VSG, 2021)
- LCI oil and gas supply (ecoinvent v3.9.1- v3.11, ongoing for v3.12)
- LCI oil and gas supply (CarbonMinds, since 2023, ongoing)

➤ Here we present our own conclusions not related to a specific project

Updates 2018-22 on behalf of the Swiss Federal Offices for the Environment and Energy,  
the Swiss Gas & Oil Associations and ecoinvent

# **EXTRACTION OF CRUDE OIL AND NATURAL GAS**

## Sources of methane emissions

- Release of unburned natural gas to the atmosphere, due to production and processing of crude oil & natural gas.
- In industry: Unwanted release of natural gas in technical process chain, e.g. due to insufficient flaring, accidents or leakage.
- However, it may also occur due to forced changes in geological structures (e.g. due to fracking).

➤ Satellite measurements show that emissions are more diffuse and less connected to the flaring rate than expected by industry



## Flaring, venting and fugitive emissions

- Country-specific satellite data are available for all emission sources
- Flaring for oil and gas combined (Worldbank 2022 & Skytruth 2020)
- Venting and fugitive emissions (IEA 2022) distinguished for
  - oil & gas
  - on- & offshore
  - up- & downstream
  - conventional & unconventional



## Methane emission: consulted and used sources of information (Examples for relevant extracting countries)

Source	Crippa et al. 2019, data from EDGAR, up- & downstream (2012)	IOGP 2020, upstream only (2019)	UNFCCC 2020, up- & downstream (2018)	UNFCCC 2020, up- & downstream (2018); Production: BP (2018)	IEA 2022, up- & downstream (2019); Production: BP (2019)	IEA 2022, upstream (2019); Production: BP (2019)
Unit	kg/kgOE	kg/kgOE	kg/kgOE	kg/kgOE	kg/kgOE	kg/kgOE
<b>Russian Federation</b>	8.76E-03	1.12E-03	6.37E-03	6.16E-03	1.26E-02	1.11E-02
<b>Saudi Arabia</b>	4.45E-03	1.00E-04	n.a.	n.a.	4.33E-03	4.03E-03
<b>United States</b>	8.26E-03	1.25E-03	1.37E-02	5.58E-03	9.13E-03	7.40E-03
<b>Global</b>	1.01E-02	6.01E-04	7.93E-03	4.15E-03	1.06E-02	8.86E-03

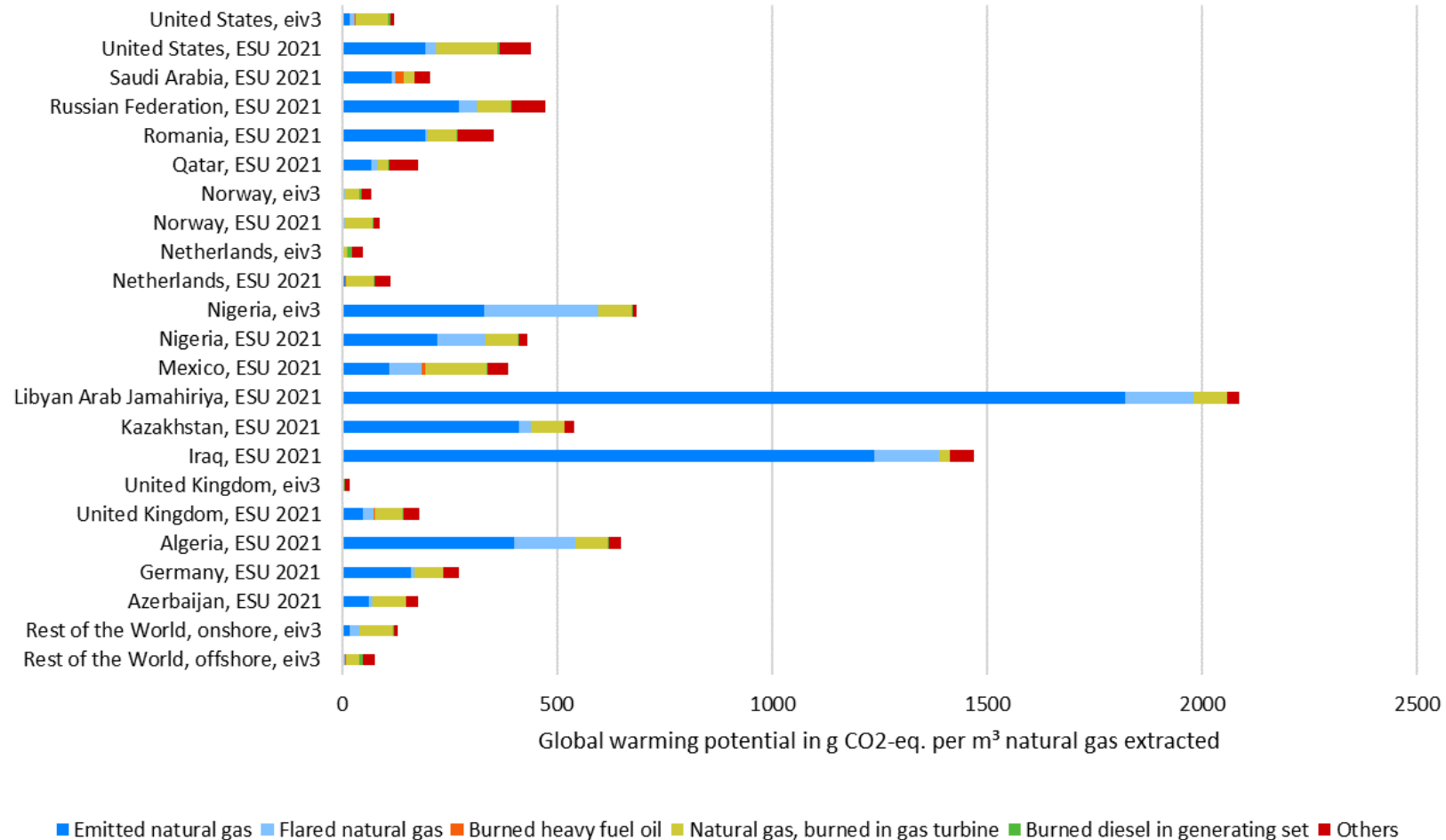
- Methane emissions reported by IOGP “industry data” are an order of magnitude lower than calculated from national and global emissions in relation to national and global production data

## Composition of vented natural gas

88% Methane by volume

- For a time-horizon of 100 years, methane has a 30-times higher Global warming potential than CO<sub>2</sub> ([IPCC 2013](#)).

## Natural gas extraction: GWP compared to ei v3.8



➤ In ecoinvent v3.8, emissions of natural gas were highly underestimated

Own update to harmonize assumptions for cumulative data in 2021

# **INFLUENCE ON PLASTICS DATA**

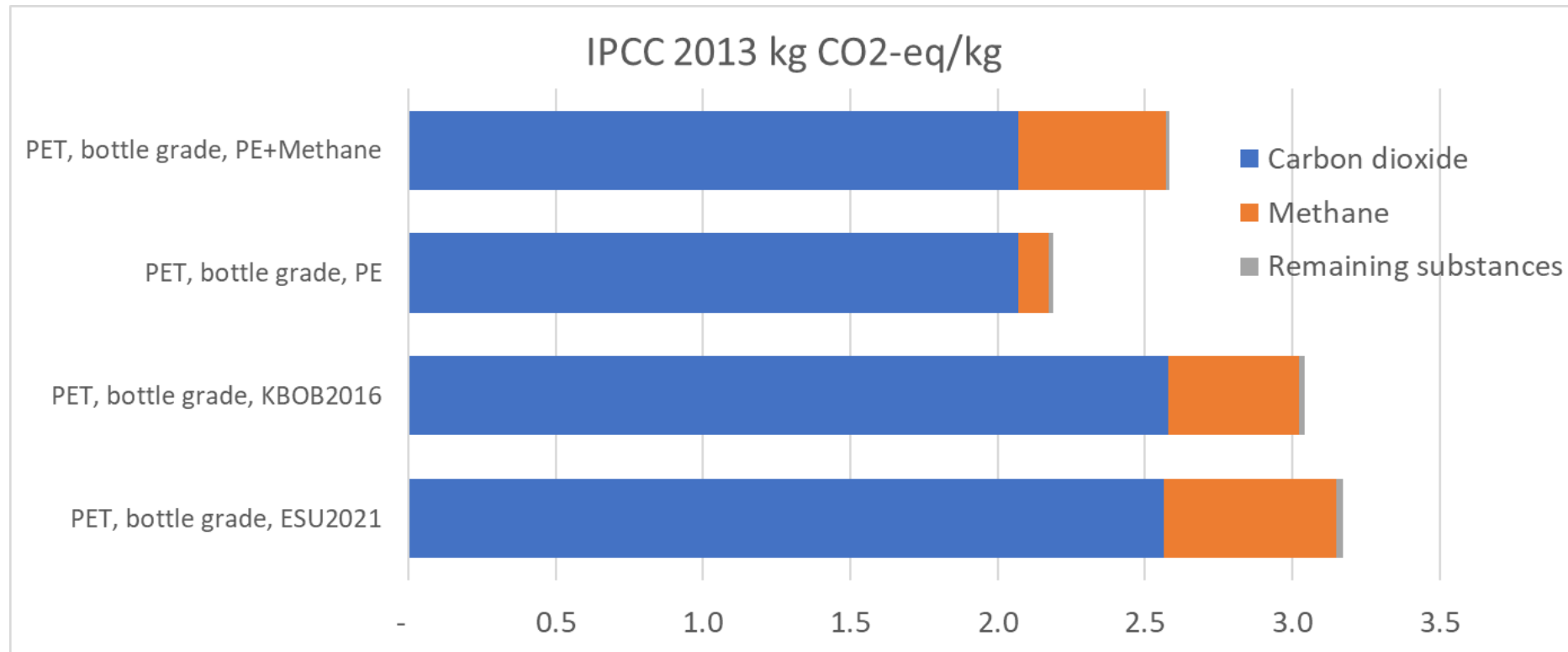
## What is the contribution for plastics?

- PlasticsEurope data partly available only in aggregated form
- Bias for system processes needs to be avoided
- Estimation of surplus methane release based on LCI for crude oil and natural gas resource use

methane, fossil/kg = oil, crude in ground/kg \* 0.0135 kg/kg + gas, natural/m<sup>3</sup> \* 0.0089 kg/m<sup>3</sup>

- Integrated in system processes provided by Plastics Europe and imported to ESU-database 2021

## Results for plastics, example PET

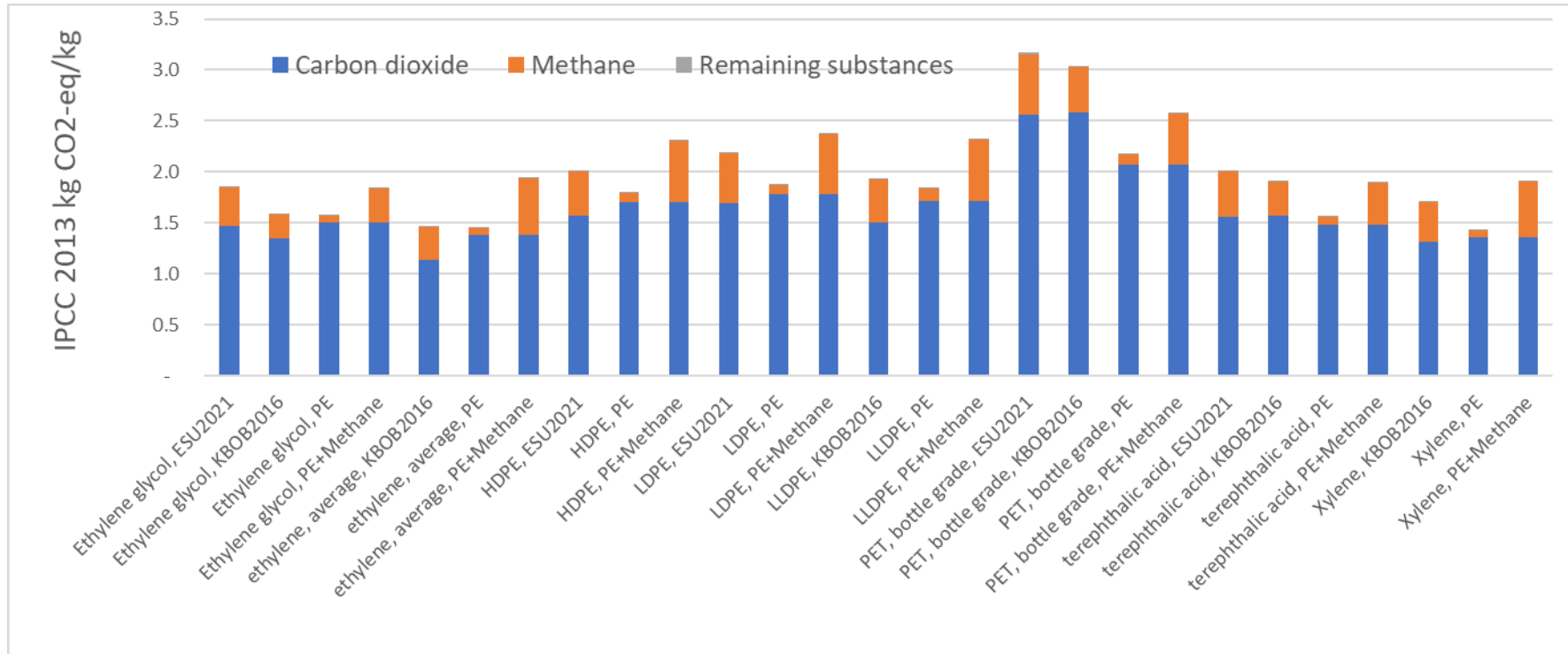


ESU 2021 - Unit processes with CH<sub>4</sub>  
PE - system processes

KBOB 2016 - Unit processes without CH<sub>4</sub>  
PE+Methane - including methane

- Increase “at gate” due to methane 15-30%
- Effect of methane less pronounced due to further CO<sub>2</sub> emissions from fossil fuels
- Data for several plastics integrated in ESU database 2021

# Results all plastics



ESU 2021 - Unit processes with CH4  
PE - system processes

KBOB 2016 - Unit processes without CH4  
PE+Methane - including methane



## Status Plastics Europe

- PlasticsEurope addressed the issue in 2021 after our first publications
- <https://plasticseurope.org/sustainability/circularity/life-cycle-thinking/eco-profiles-set/>
- Different consultancies like IFEU and Sphera modelling the data
- Newer data at least of IFEU address the issue of unintended methane emissions while older data might not

➤ Older data are available at ESU with a rough estimation for increased methane emissions

Latest updates on behalf of the ecoinvent and CarbonMinds 2024/25

# **EXTRACTION OF CRUDE OIL AND NATURAL GAS**

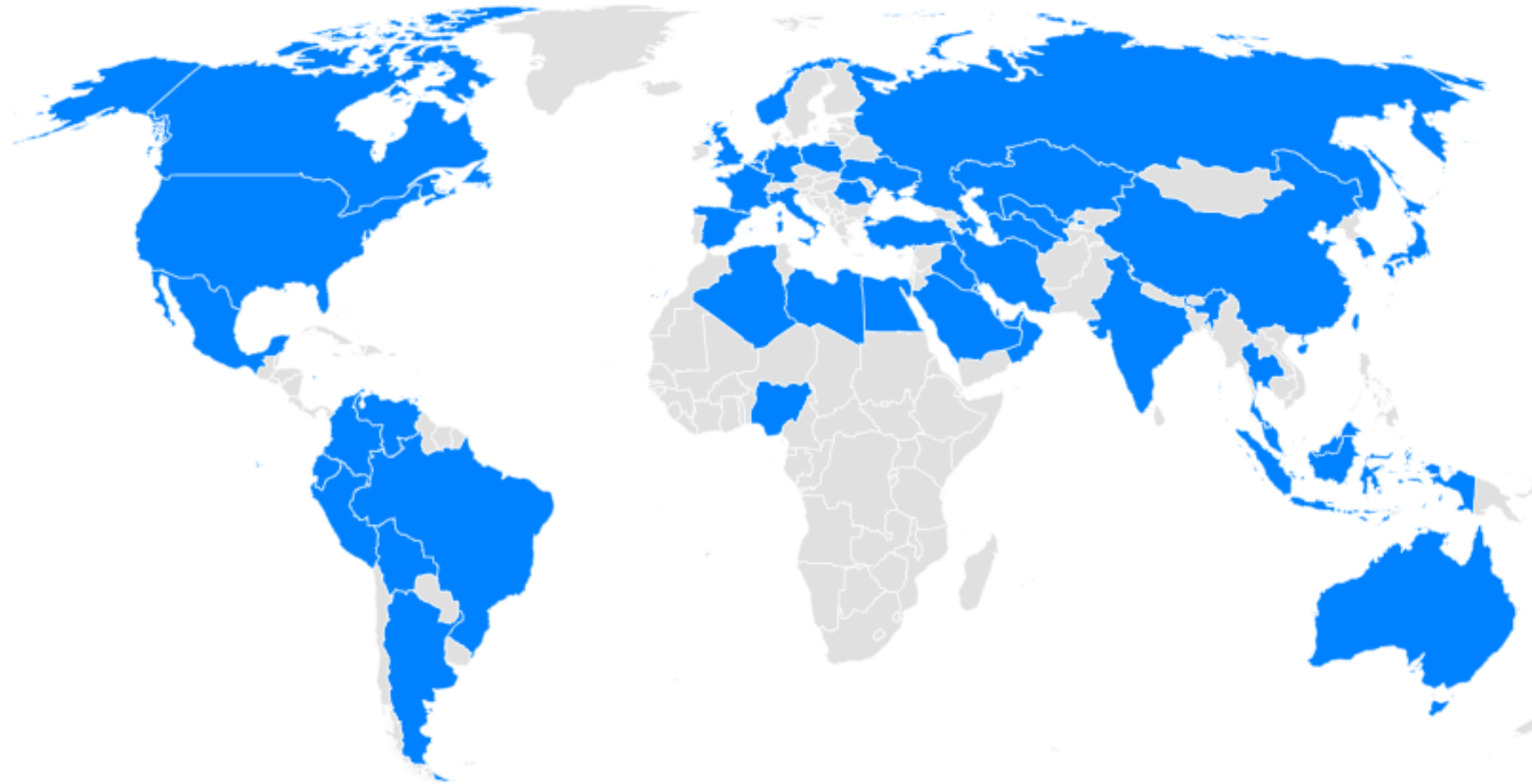
## Starting point: Regular requests for updates of LCIs

- Crude oil and natural gas extraction and transportation
- Last updates in 2024 (ongoing)
- Reference year: 2023
- Documentation of harmonized LCIs in different formats and for different implementations



Source: <https://media.npr.org>

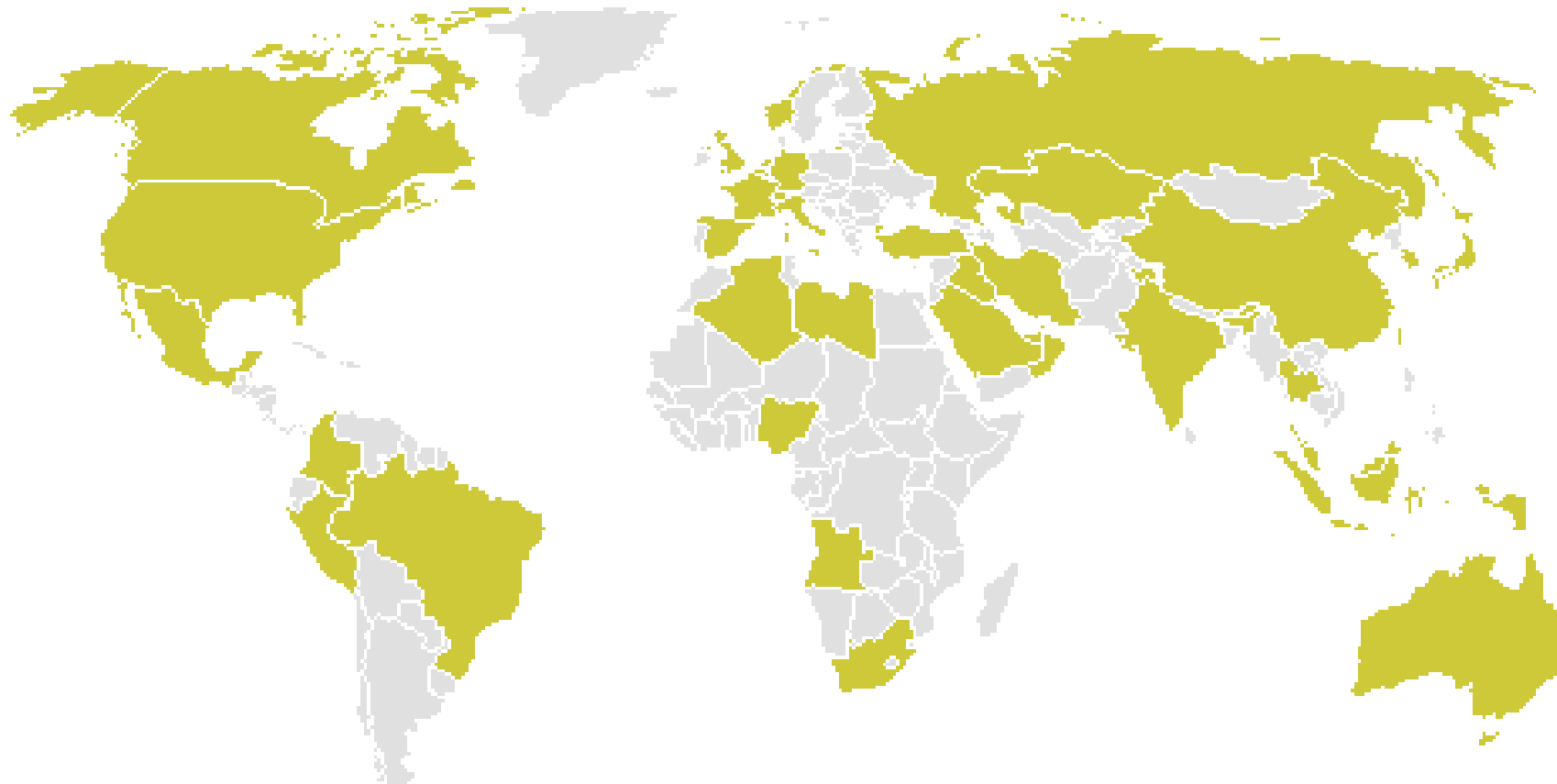
## Countries covered: On- and offshore extraction of crude oil & natural gas



Meili et al 2023 - Life cycle inventories of crude oil and natural gas extraction, available on <https://esu-services.ch/publications/energy/>

➤ 49 countries covering 96% of global oil and gas production

# Specific countries covered: Markets for crude oil



Meili et al 2024 - Life cycle inventories of long-distance transport of crude oil, available on <https://esu-services.ch/publications/energy/>

- 40 countries plus Global, European and North American region
- More possible on request



# Specific countries covered: Markets for natural gas



Bussa et al 2023 - Life cycle inventories of long-distance transport and distribution of natural gas, available on [esu-services.ch/publications/energy/](https://www.esu-services.ch/publications/energy/)

- 15 countries plus Global, European and North American region
- 31 additionally offered for update in 2024, more possible on request

# Main data sources

## Extraction:

- Production figures: Energy institute 2024
- Methane and flaring emissions: IEA 2024 and World Bank 2024
- Consumption of energy, freshwater and other key indicators: IOGP 2024

## Oil transport:

- Market mixes: Energy institute 2024
- Pipeline-distances: google-maps,
- Shipping distances: searates.com and sea-distances.org

## Gas transport and distribution:

- Market mixes (including liquefied natural gas): Eurostat 2024 and Energy institute 2024
- Pipeline-distances: entsog.eu, google-maps, EIA.gov
- Shipping distances (LNG): sea-distances.org

➤ Data partially collected from Excel-tables, PDF-reports or online-tools

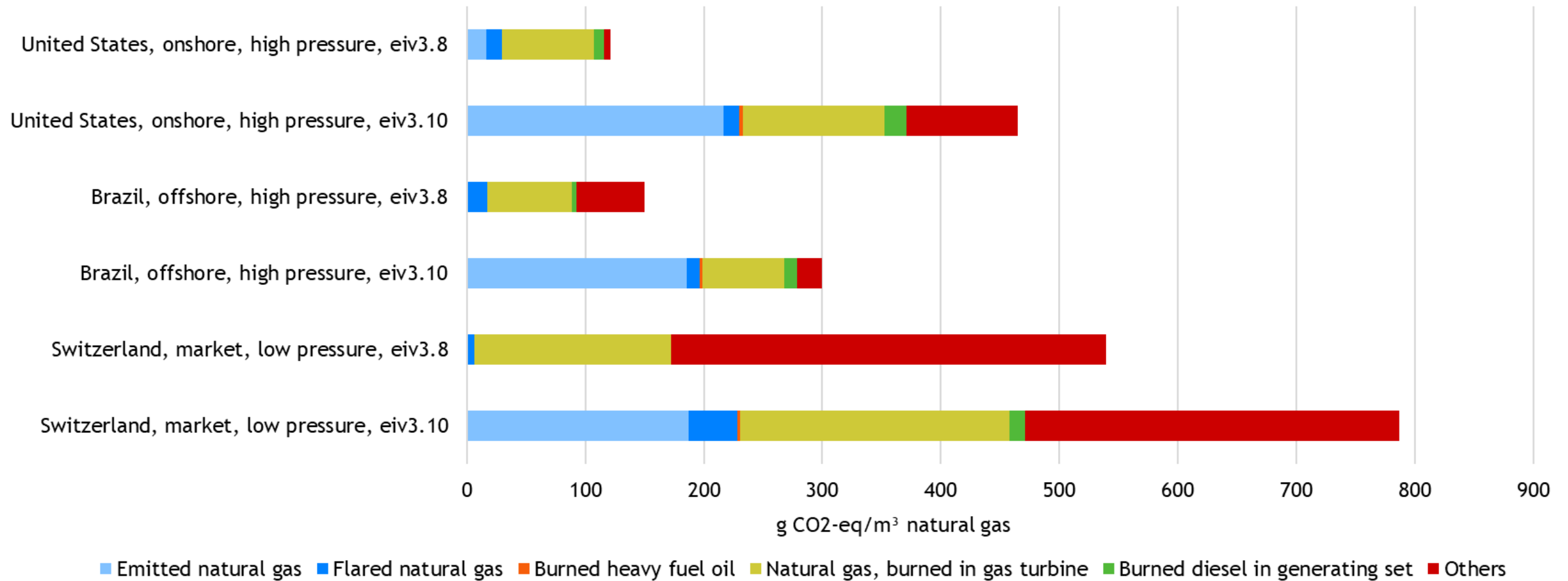


# Archetype models for LCI based on global statistics

	B	F	G	J	K	L	P	Q	R	V	W	X	AB	AC	AD	AE
	US_obs	Name	Location	InfrastructureProcess	Unit	combined gas and oil production offshore	crude oil, at production offshore	natural gas, at production offshore	combined gas and oil production onshore	crude oil, at production onshore	natural gas, at production onshore	combined gas and oil production	combined gas and oil production offshore	combined gas and oil production onshore	Data for this scenario	Explanation for Data entry
3																
4		Location				US_obs	US_obs	US_obs	US_obs	US_obs	US_obs	US_obs	US_obs	US_obs	US_obs	
5		InfrastructureProcess				0	0	0	0	0	0	0	0	0	2016_obsolete	
6		Unit				a	kg	Nm3	a	kg	Nm3	a	kg OE	kg OE	kg OE	
14	resources, in ground	Oil, crude	-	-	kg	1.02E+11	100%		4.54E+11	100%		5.56E+11			5.56E+11	kg crude oil extracted per country and year (total kg on- and offshore per year)
15		Oil, crude	-	-	kg	9.36E+6	100%		4.16E+7	100%		5.09E+7	4.29E-5	4.29E-5	4.29E-05	Value calculated based on entries below.
16		Gas, natural/m3	-	-	Nm3	1.38E+11		100%	6.12E+11		100%	7.50E+11			7.50E+11	Billion cubic meters natural gas extracted per country and year (total m3 on- and offshore per year)
17	water resource	Water, unspecified natural origin,	GLO	-	m3	0	100%	0%	1.63E+8	100%	0%	1.63E+8		3.60E-4	3.60E-04	Fresh water withdrawn for enhanced oil recovery
18		Water, salt, ocean	GLO	-	m3	3.68E+7	100%	0%	0	100%	0%	3.68E+7	3.60E-4		3.60E-04	salt water use for offshore production assumed to be the same as freshwater use onshore
19		Water, fossil	GLO	-	m3	9.60E+07	100%	0%	2.64E+08	100%	0%	3.60E+08	9.40E-4	5.81E-4	3.60E-04	Line stays empty (used to balance water input and output)
20	water emission	Water, US_obs	-	-	m3	0	100%	0%	4.27E+8	100%	0%	4.27E+8		9.41E-4	9.41E-01	assumed to be equal to produced water discharged
21		Water, US_obs	-	-	m3	1.33E+8	100%	0%	0	100%	0%	1.33E+8	1.30E-3		1.30E+00	assumed to be equal to produced water discharged
22		Water, US_obs	-	-	m3	0	100%	0%	0	100%	0%	0	0	0	0.00E+00	Line stays empty (used to balance water input and output)
23		discharge, produced water, offshore	OCE	0	kg	1.33E+11	100%	0%	0	100%	0%	1.33E+11	1.30E+0		1.30E+00	Amount of untreated, produced water discharged offshore per kg OE produced of
24		discharge, produced water, onshore	GLO	0	kg	0	100%	0%	4.27E+11	100%	0%	4.27E+11		9.41E-1	9.41E-01	Amount of untreated, produced water discharged onshore per kg OE produced or
25	technosphere	chemicals inorganic, at plant	GLO	0	kg	1.21E+8	47%	53%	5.36E+8	47%	53%	6.56E+8	5.53E-4	5.53E-4	5.53E-04	Inorganic chemicals used for enhanced oil recovery
26		chemicals organic, at plant	GLO	0	kg	9.19E+7	47%	53%	4.09E+8	47%	53%	5.01E+8	4.22E-4	4.22E-4	4.22E-04	Organic chemicals used for enhanced oil recovery
27		transport, lorry >16t, fleet average	RER	0	tkm	1.84E+8	47%	53%	8.18E+8	47%	53%	1.00E+9	8.45E-4	8.45E-4	8.45E-04	Distance for chemical transport by lorry (km) multiplied by sum of chemicals (kg) /
28		transport, freight, rail	RER	0	tkm	1.27E+8	47%	53%	5.66E+8	47%	53%	6.94E+8	5.85E-4	5.85E-4	5.85E-04	Distance for chemical transport by rail (km) multiplied by sum of chemicals (kg) /
29	Infrastructure	well for exploration and production, offshore	OCE	1	m	8.07E+5	47%	53%	0	0%	0%	8.07E+5	3.70E-6		3.70E-06	Average meter of well to produce one kg of oil equivalent

- Model calculates country/region-specific data based on selection
- Automated export in EcoSpold1 (XML-files) or excel-tables by using VBA

# Exemplary results: Natural gas



➤ Main increase due to new comprehensive satellite data for methane emissions

## Data quality

- **Consistent** international data sources for issues like energy and freshwater use, flaring, methane release and oil spills
- **Harmonized assumptions**, cross-checked between different countries
- **High level of completeness** in terms of environmental impacts:
  - Top-down statistics deliver full picture e.g. of methane emissions from global satellite-data
  - Bottom-up studies deliver values for generic estimates for issues like onsite-pipeline or use of chemicals

➤ Good basis for daily work and regular updates

## Publication

Several LCI reports are available online

<https://esu-services.ch/publications/energy/>

- Life cycle inventory analysis (LCI and not a full LCA)
- Current and future update available in ecoinvent and Carbon Minds-database

# CHALLENGES FOR UPDATES IN 2016-24 COMPARED TO 1994-2003

## First comprehensive LCI in 1994-96: *Ökoinventare von Energiesystemen* *LCA of LPG and kerosene in India*

- Estimates partly based on bottom-up approaches
- Detailed emission data available from measurements done at universities
- Comprehensive inventory of pollutants, e.g. detailed emission profiles for single NMVOC
- Literature sources in printed format
- Direct contacts e.g. to oil extracting companies and refineries
- No electronic documentation, only numbers

## Updates 2000-2003: ecoinvent v1 and v2

- Some data are available in environmental reports of single companies
- Focus on energy use and main pollutants
- No newer data for many pollutants reported in the first version
- Different data sources with different scopes had to be combined for an estimate
- EcoSpold v1 for electronic documentation



# Updates in 2016-21: Swiss UVEK/KBOB/ESU databases

- Most information available on the internet
- Data available from global statistics, large measurement campaigns or industry associations
- More information found for European situation and less for Africa, Russia or Middle East
- Reports of global oil companies cannot be assigned to single countries nor single stages often only relative changes are shown → **Not suitable for LCI work anymore**
- Focus in literature on main air pollutants like CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub>, NMVOC, CO
- No current information found for specific pollutants reported in former versions (heavy metals, single NMVOC, water pollutants)

# Updates in 2022-24: ecoinvent and CarbonMinds database

- Global annual statistics (BP, IOGP, Worldbank, IEA)
- Satellite measurements for CH<sub>4</sub> (IEA methane tracker)
- Focused research on water balance (based on IOGP data)
- Established automatized models for transports of oil and gas
- High efforts for electronic documentation
- Focus on market shifts e.g. due to Russian attack on Ukraine

➤ Scope of data sources changes annually and needs manual refinement of models

## Further reading

- Life cycle inventory analysis (LCI and not a full LCA)
- All reports are available on <https://esu-services.ch/publications/energy/>
- Full SimaPro library including updates for refinery based on UVEK 2018 with latest updates offered by ESU-services  
<http://www.esu-services.ch/fileadmin/download/tender/ESU-background-databases.pdf>
- UNEP International Methane Emissions Observatory coordinates different activities  
<https://www.unep.org/topics/energy/methane/international-methane-emissions-observatory>

## Summary

- Full methane emissions need to be accounted for all products from oil and gas
- Industry measurements do not show the full methane picture
- Changes mainly relevant for cradle-to-gate analysis (plastics, chemicals)
- Changes are relevant for relative comparisons between fossil-based products with biobased and other alternative products
- Regular updates of mixes and methane emissions necessary

## Status of implementation

- Integrated in ecoinvent, CarbonMinds, ESU and FOEN databases
- Partly integrated in PlasticsEurope inventories
- To our knowledge not yet integrated in Sphera, IOGP, Eurobitumen inventories

➤ Uptake of knowledge on methane available since 2018 takes to much time

## Key messages oil and gas supply

1. Consumption mix plays important role and changes
2. Differentiation between Pipeline and LNG-imports matters
3. Effect of methane from extraction less pronounced for natural gas than for crude oil due to higher other downstream emissions
4. Methane mainly relevant for materials and to a lesser extend for energy uses

## Outlook /ideas for future projects

- Plans to use API and more direct data imports
- Updates regarding specific issues /extension of models to include markets for fossil fuel products including shares of biofuels
- Cross-check global data with country specific data
- Link PlasticsEurope and other industry data to up-to-date LCI
- Include future emissions due to abandoned oil and gas fields
- Harmonize and update data for coal (ongoing at PSI)  
(effect seems to be of low relevance)

- Current updates available in different databases (different implementations)
- Happy to discuss future project ideas/extensions



# Thank you very much for your attention!

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- Plastics Europe, RER
- Swiss federal office for the environment, CH
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