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Alliance for Batteries Technology, Training and Skills

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Other Battery Applications and Skills Transition

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Executive Summary

The first part of this report provides a summary of other battery applications which were analysed during the desk research throughout 2022 (in ALBATTS WP4 and WP5) to provide state-of-the-art information about the following areas and battery applications, namely:

- **Other Industrial and Stationary Battery Applications**
    - data centres;
    - renewable power farms;
    - residential applications;
    - **off-road type of heavy machinery (heavy work machines)**
        - mining equipment;
        - forest machines;
        - cargo handling; and
        - heavy construction equipment.
- **Other Mobile Battery Applications**
    - **heavy-duty vehicles** – trucks, buses, utility vehicles;
    - vans;
    - motorbikes;
    - micro-mobility devices;
    - e-bikes;
    - **aerospace** – drones and planes;
    - trains; and
    - inland waterway vessels.

These areas were a continuation of first and second desk research which investigated the overall battery value chain and battery gigafactory.

The second part of this report provides insights into the collected information and data on the "skills transition", which aims to identify the changes in the battery sector in the context of current or upcoming trends and how the workforce and needed competences will be affected.

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List of Abbreviations

UPS	...	Uninterruptible Power Supply
BESS	...	Battery Energy Storage System
EV	...	Electric Vehicle
SW	...	Software
BEV	...	Battery Electric Vehicle
ICE	...	Internal Combustion Engine
MHEV	...	Mild Hybrid Electric Vehicle
CO_2	...	Carbon Dioxide
FHEV	...	Full Hybrid Electric Vehicles
CAR	...	Centre for Automotive Research
OEM	...	Original Equipment Manufacturer
SME	...	Small-Medium Enterprise
IRENA	...	International Renewable Energy Agency
ILO	...	International Labour Organization
EU	...	European Union
GWEC	...	Global Wind Energy Council
GW	...	GigaWatt
PV	...	Photovoltaic

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1 Other Battery Applications

As introduced in the executive summary, this section provides a summary of other battery applications and links relevant information and further reading.

1.1 OTHER INDUSTRIAL AND STATIONARY BATTERY APPLICATIONS

The following applications and areas are shortly introduced and linked. The chapters are based on the following publications[1, 2, 3].

1.1.1 Data Centres

Usage of batteries and UPS systems as a backup power source. The chapter discusses the criticality and essentiality of these battery applications and related issues of carbon footprint, renewable energy applications and various trends of shifting towards batteries from diesel generators as a backup solution.

Access the chapter

1.1.2 Renewable Power Farms

Application of Battery Energy Storage (BESS) in the context of renewable energy and connected trends such as the war in Ukraine, policy, energy diversification, and compliance with the Green Deal. The most significant renewable energy sources are covered: 1) wind power farms, 2) hydroelectric power, and 3) solar plants.

Access the chapter

[1] ALBATTS project. Desk Research III: Other Mobile Battery Applications. ALBATTS Project Website. Retrieved November 20, 2022, from https://www.project-albatts.eu/Media/Publications/67/Publications_67_20220831_161257.pdf

[2] ALBATTS project. Battery job roles, skills, and competencies, ALBATTS Work Package 4 Research of 2022. ALBATTS Project Website. Retrieved November 20, 2022, from https://www.project-albatts.eu/Media/Publications/75/Publications_75_20221107_8243.pdf

[3] ALBATTS project. Skills and Job Roles in Battery Applications Supporting the Modern Society, D4.7 - Desk research and data analysis for sub-sector ISIBA- Release 3. ALBATTS Project Website. Retrieved November 20, 2022, from Publications_68_20220912_82848.pdf (project-albatts.eu)

1.1.3 Heavy Work Machines

Entering the border between the stationary and mobile applications of batteries, namely in 1) mining equipment; 2) forest machines; 3) cargo handling, and 4) heavy construction equipment.

Mainly the trend of replacement of diesel-powered machines with electrified or hybrid solutions is discussed.

Access the chapter

1.1.4 BESS in Residential Applications

Reasons and trends causing BESS solutions and renewable energy demand in residential areas and facilities are discussed.

Access the chapter

1.2 OTHER MOBILE BATTERY APPLICATIONS

The following applications and areas are shortly introduced and linked.

1.2.1 Heavy-Duty Vehicles

Mobile applications of batteries in trucks, buses, and utility vehicles are discussed in the context of where they stand in electrification. Specific technologies and trends are discussed.

Access the chapter

1.2.2 Vans

Vans' electrification and specifics compared to the other commercial vehicles are drawn.

Access the chapter

1.2.3 Motorbikes, Micro-mobility, e-bikes

The electrification and connected trends of customer demand and new business models of shared mobility connected to motorbikes, micro-mobility, and e-bikes are discussed.

Access the chapter

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1.2.4 Aerospace

The usage of batteries in space applications such as spaceships or satellites is being discussed. Other applications in drones or planes are outlined.

Access the chapter

1.2.5 Inland Waterway Vessels

Electrification of vessels in city centres and areas where clean air is desired.

Access the chapter

1.3 JOB ROLES AND SKILLS NEEDS

Job roles and skills needs within this domain were analysed and categorised by the production lifecycle. The following categories were identified, and needed skills and job roles based on the job advertisements were outlined:

- Design and Development;
- Manufacturing;
- Maintenance;
- Sales, Services, and Support or Technical Project Management.

Please see the following chapters for more details:

- Industrial and Stationary Applications
- Mobile Applications

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2 Skills Transition

This section defines the Skills Transition as a concept and provides background for the topic. The goals of the analysis and methodology are established as well.

2.1 DEFINITION OF THE CONCEPT

The term transition can be understood as any period of change[4]. When speaking about skills/competences and knowledge, or more precisely about the re-/up-skilling of the workforce, in this context, the skills transition means the change of needed skills/competences or knowledge during his life or career.

The world today is fast-paced, and the trends are changing rapidly, meaning that the skills and education level required is not constant during individuals' lives. In this context, the skills transition could be understood as a need for re-/up-skilling for an individual to gain new skills or knowledge to transition into a new job position in the same or new sector (re-skilling). This role does not have to be only new, but it can concern improving the skills needed for the current role (up-skilling).

Individuals may be students, newcomers to particular industries or those who have worked in specific industries or positions for multiple years.

2.2 METHODOLOGICAL APPROACH

The methodological approach for this study is to analyse relevant and available studies, white papers, or other sources focused on:

- Employment status in various countries and regions and the implications for future years in connection to the transition of a specific sector (e.g. automotive) concerning various industries, job profiles and skills of the workforce and their suitability to transition into other sectors;
- Projections and scenarios on employment, job losses, and transitional pathways of the workforce in future years;

[4] Clafferty, Elaine & Beggs, B.J.. (2016). Transition Skills and Strategies. 10.13140/RG.2.2.10806.91209.

- How is the skills transition influenced by current trends and future trends, and how this contributes to the needed skills/competences or job roles;

The analysis is done for mobile applications of batteries and the renewable energy sector. Based on the inputs, generalisation of the data and findings will be made to provide implications for the battery sector and projections for the future.

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3 Skills Transition – Mobile Applications of Batteries

This section summarises selected studies, white papers or other sources for further evaluation and conclusion drawing for mobile battery applications.

3.1 TRENDS INFLUENCING THE SKILLS TRANSITION

The following broader trends were identified to influence the skills transition within the mobile applications of batteries. Based on the following publication[5].

3.1.1 The Resilience of the industry

This trend is mainly connected to the supply chains (global and regional clusters) and the **need for security and resiliency**, recently **accelerated by the Covid-19 pandemic** and **war in Ukraine** and the shortages of semiconductors, for example.

This leads to the **increased importance of electronics and software** – new technologies, lowered barriers to enter the market and **shortages in skilled labour** resulting in **cross-sectoral competition for talent**.

3.1.2 Green transition and Sustainability

For example, the growing demand for EVs and renewable energy solutions to reduce the carbon footprint affects labour demand. Ultimately new **electric vehicle value chains** require a skilled workforce, such as researchers, engineers, or technicians (electrical, electrochemical, mechatronic, or software related).

In addition, the 2035 milestone for phasing out the sales of new non-zero emission cars is still perceived with arguments on job losses and a decline in the value of the automotive sector.[6]

[5] Directorate-General for Internal Policies of the Union (European Parliament), Brown, Flickenschild, Mazzi, Gasparotti, Panagiotidou, Dingemanse, & Bratzel. (2021, October 21). The future of the EU automotive sector. Photo of Publications Office of the European Union. Retrieved November 20, 2022, from https://op.europa.eu/en/publication-detail/-/publication/56ff3240-32e4-11ec-bd8e-01aa75ed71a1/language-en

[6] Hrubý, M. EU Monitor: Recharging the Czech Eu presidency. EUROPEUM.org. Retrieved November 20, 2022, from https://europeum.org/en/articles/detail/4964/eu-monitor-recharging-the-czech-eu-presidency

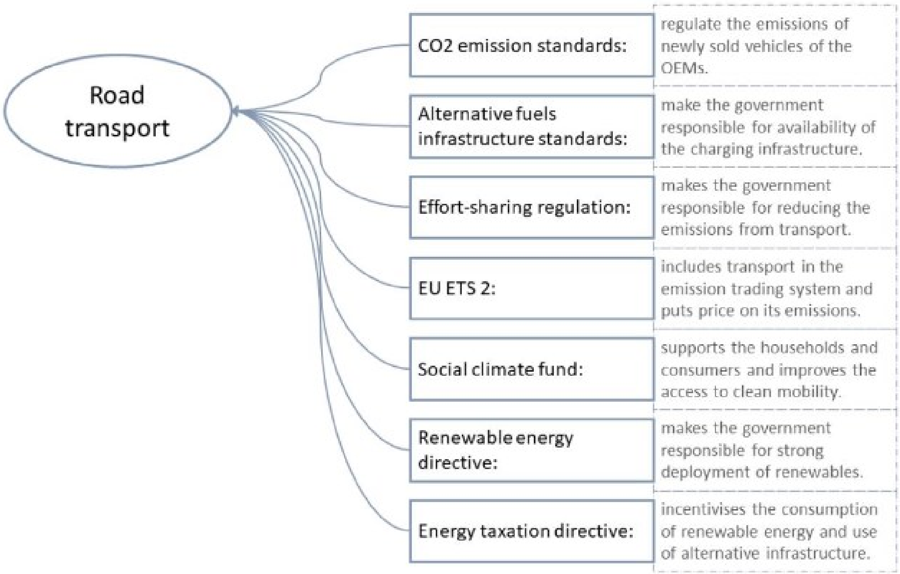

Figure 1: Regulations and directives targeted at road transport emissions

3.1.3 Digital transition

Going from **hardware to software** and increasing importance of **digital products, services, competition, and new technologies** (Artificial Intelligence, Machine Learning, Automatisation, or other). The trend is connected to the robust innovation capabilities in connectivity (connected vehicles, IoT, and others), and the lack of skills and skilled workforce in terms of software, digital competencies, or software engineering which is likely to intensify unless there is a sufficient number of talents attracted.

3.2 AFFECTED SKILLS AND WORKFORCE – EXAMPLE SCENARIOS AND STUDIES

Previously identified trends significantly affect the following areas, skills and workforce needs. Due to the identified trends, the demand for skills and a skilled workforce is changing. Lack of skills in SW engineering or electronics, together with global competition for talent compared to job losses due to the electrification of powertrains with suppliers being particularly vulnerable. The more batteries imported and not produced domestically, the worse the impact on future automotive value added and jobs.

The number of jobs that will be lost through electrification and other trends depends on the underlying scenarios that are presented below.

3.2.1 Electric Vehicle Transition Impact Assessment Report 2020 - 2040

This study assumes that **up to 501,000 jobs** in Europe will be lost by 2040 in parts of the value chain, mainly within ICE suppliers[7, 8]. This would mean a **reduction of 84 % of the current jobs in the ICE value chain**. The losses are partially compensated by the **BEV powertrain production** that is expected to **create 226,000** jobs, but still, there could be an overall loss of 275,000 jobs until 2040 (Ibid).

This study looks at three scenarios, as seen in the figure below.

	Mixed technology	EV-only	Radical
2024	< 1m EV chargers Incentives for Battery Electric Vehicles (BEV) purchase but not for the charging infrastructure	1m EV chargers Incentives for BEV purchase and for the charging infrastructure	> 1m EV chargers Incentives for BEV and large incentives for the charging infrastructure
2026	Technology open EURO 7, including Mild Hybrid Vehicles (MHEV) in operation	Technology restrictive EURO 7, Full Hybrid Vehicles (FHEV) favoured	Very technology restrictive EURO 7, no MHEV allowed
2030	Equivalent -50% tailpipe CO_2 emissions with A-fuels credit of -20g	Equivalent -60% tailpipe CO_2 emissions with A-fuels credit of -7g	0g CO_2 target for new vehicle fleet
2035	Equivalent -65% tailpipe CO_2 emissions with A-fuels credit of -30g	0g CO_2 target for new fleet with A-fuels credit of -10g	Explicit end of ICE vehicle sales

Figure 2: Green Deal policy scenarios

[7] CLEPA. 2021. „Electric Vehicle Transition Impact Assessment Report 2020 - 2040“. Transition Impact Study. European Association of Automotive suppliers. https://clepa.eu/strategy-transition-impact-study/.
[8] CLEPA. 2021. „Electric Vehicle Transition Impact Assessment Report 2020 - 2040“. Summary Brochure. European Association of Automotive suppliers. Study-Brochure-Electric-Vehicle-Transition-Impact-Assessment-2020-2040.pdf (clepa.eu).

The technical part of the study focuses on the impact of three different Green Deal policy scenarios on employment and value-add among European automotive suppliers in 2020-2040. The scenarios represent a 1) mixed technology approach, 2) an EV-only approach as proposed in the 'Fit for 55' package, 3) and a radical EV ramp-up approach.

All three scenarios assume accelerated electrification to meet climate goals, with a high market share for electric vehicles by 2030 of more than 50 %, almost 80 %, and close to 100 %, respectively.

According to the EV-only approach ("the middle" scenario in terms of the workforce), there will be the following effects:

- There will be a slight employment increase in ICE powertrains expected between 2020 and 2025 due to advanced ICE technologies (EURO7) and demand increase, **followed by a constant decline**;
- **501k jobs in ICE powertrain will become obsolete from now until 2040;** this is about 84 % of current ICE jobs;
- EV powertrain creates 226k new opportunities, **but we still have a net loss of 275k jobs until 2040**;
- There will **not** be a 1:1 compensation from ICE to EV powertrain employment; different companies, different skill sets, different regions and at different times;
- **70 % of ICE job losses from now until 2040 will occur in just five years** – 2030 – 2035. 2030 is "just around the corner" for an industry with **a product development lead time of around 5 – 8 years**;
- The more abrupt the loss of the ICE powertrain (35 % of overall employment), the greater the pressure on regional economies and the more limited the time to re- and up-skill workers.

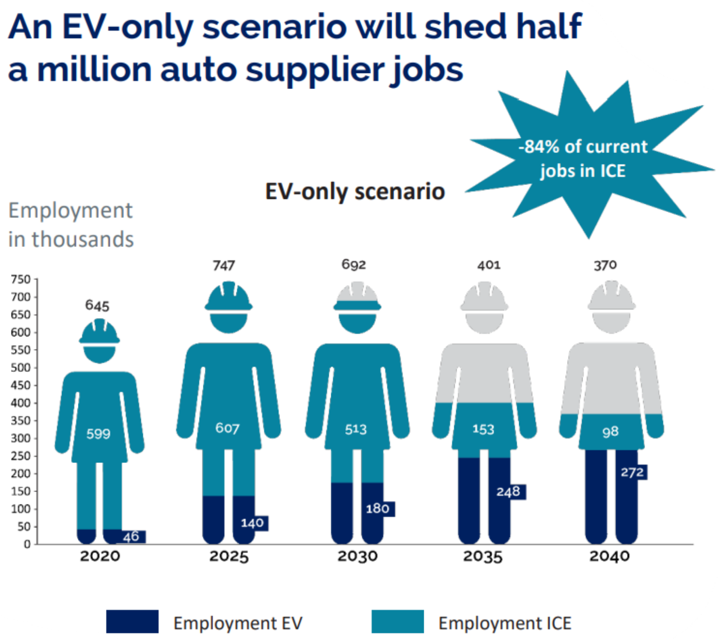

Figure 3: EV-only Scenario Employment Projection

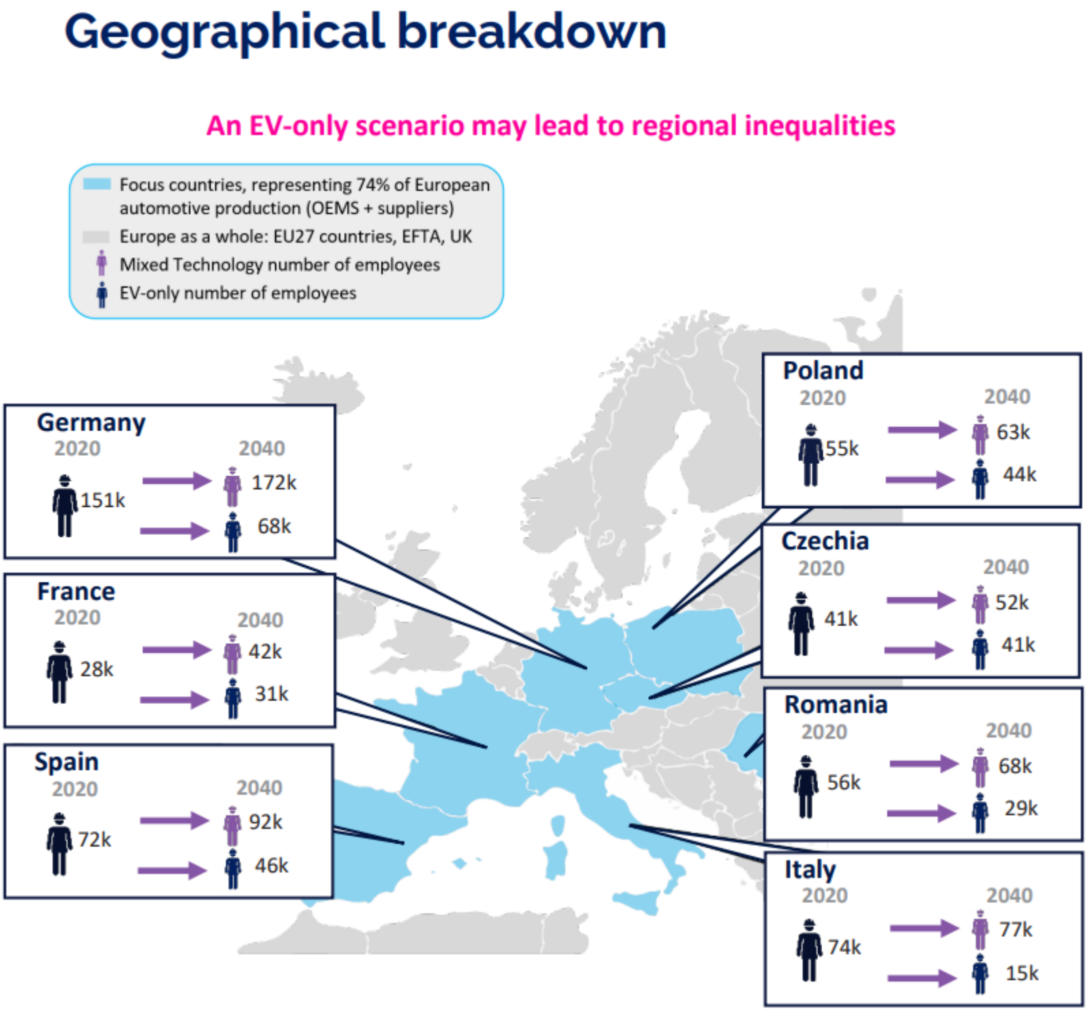

Figure 4: EV-only Scenario Geographical Breakdown

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3.2.2 Impact Of Electrically Chargeable Vehicles on Jobs And Growth in The EU

The study has more optimistic forecasts, stating that electrification could lead to a **reduction** in employment of "**around 60 % in powertrain, spare parts manufacturing and maintenance**" (2018). The study[9] also provides an interesting outlook on the changes in employment from various perspectives, as seen below.

Table 1: Sectoral employment ('000s) by share of low-emission vehicles, 2030

Share of LEV (<25 g/km)	Base case (13%) Total empl.	13%-->25% Δ empl.	13%-->30% Δ empl.
Petroleum refining	150	0.4	0.5
Automotive	2,451	-9.3	-16.6
Rubber and plastics	1,781	2.1	2.1
Metals	4,293	-0.7	-0.7
Electrical equipment	2,458	-2.1	0.4
Electricity, gas, water	2,854	6.6	9.4

Source: EC Impact Assessment page 95 and 141.

Table 2: Share of powertrains in total passenger car registrations and Employment Impact

Emission target (beyond 2020 targets)	ICE	PHEV	BEV	FCEV	Employment impact (000s)
Baseline	88.7%	6.7%	3.9%	0.7%	
20% reduction	82.6%	9.3%	6.4%	1.7%	+31
30% reduction	80.2%	10.8%	7.1%	1.9%	+71
40% reduction	72.0%	15.7%	9.7%	2.6%	+88

[9] Electrically chargeable vehicles jobs eu: FTI Consulting. Electrically Chargeable Vehicles Jobs EU | FTI Consulting. Retrieved November 20, 2022, from https://www.fticonsulting.com/emea/insights/articles/impact-electrically-chargeable-vehicles-jobs-growth-eu

Table 3: German employment, directly and indirectly, dependent on ICE

Category	Product group	Employment dependent on ICE technology	Share of total sector employment
Directly dependent	Automotive manufacturing	425,780	52.4%
	Electronic equipment	3,380	0.8%
	Machinery equipment	27,810	2.7%
	Total direct	***456,970***	
Indirectly dependent	Automotive manufacturing	44,470	5.5%
	Refinery of mineral products	8,140	44.4%
	Plastic equipment	8,150	2.4%
	Metalworking	32,140	12.5%
	Metal products	70,190	10.7%
	Total indirect	***163,090***	
Total		**620,060**	

Source: Auswirkungen eines Zulassungsverbots für Personenkraftwagen und leichte Nutzfahrzeuge mit Verbrennungsmotor, Falck et al., 2017, pages 26-27.

3.2.3 Centre for Automotive Research (CAR)

The lowest job losses are projected in a Centre for Automotive Research (CAR) study. It concludes that strict emissions limits might lead to **28,000 lost jobs in Germany, France, Italy, Spain, and Slovakia**, that is 1.9 % of the automotive employees in these countries. These countries accounted for 70 % of the total manufactured passenger cars in the EU27 in 2019 (CAR and Dudenhöffer, 2021[10]).

3.2.4 Boston Consulting Group Studies

Concluded that **up to 2.4 million jobs** will require partly high retraining in this transition by 2030 (Kuhlmann et al. 2021[11]). The figure below describes the different amounts of re-skilling needed: While 1.6 million persons need re-skilling within the same job profile, 610,000 persons have to change their job profiles slightly. In comparison, just 225,000 persons need

[10] CAR, und Ferdinand Dudenhöffer. 2021. „Tightening of EU - CO2 Requirements and the effects on Jobs in the European Auto Industry“. Duisburg: Center Automotive Research. https://www.car-future.com/media/center-automotive-research/CO2_Studie/CAR_Jobs_Study_EN.pdf.

[11] Kuhlmann, Kristian, Daniel Küpper, Marc Schmidt, Konstantin Wree, Rainer Strack, und Philipp Kolo. 2021. „Is E-Mobility a Green Boost for European Automotive Jobs?“ Boston Consulting Group. https://www.bcg.com/is-e-mobility-a-green-boost-for-european-automotive-jobs¨

radical retraining into different job profiles and industries. Just transition has to find policies to foster a smooth skill transformation.

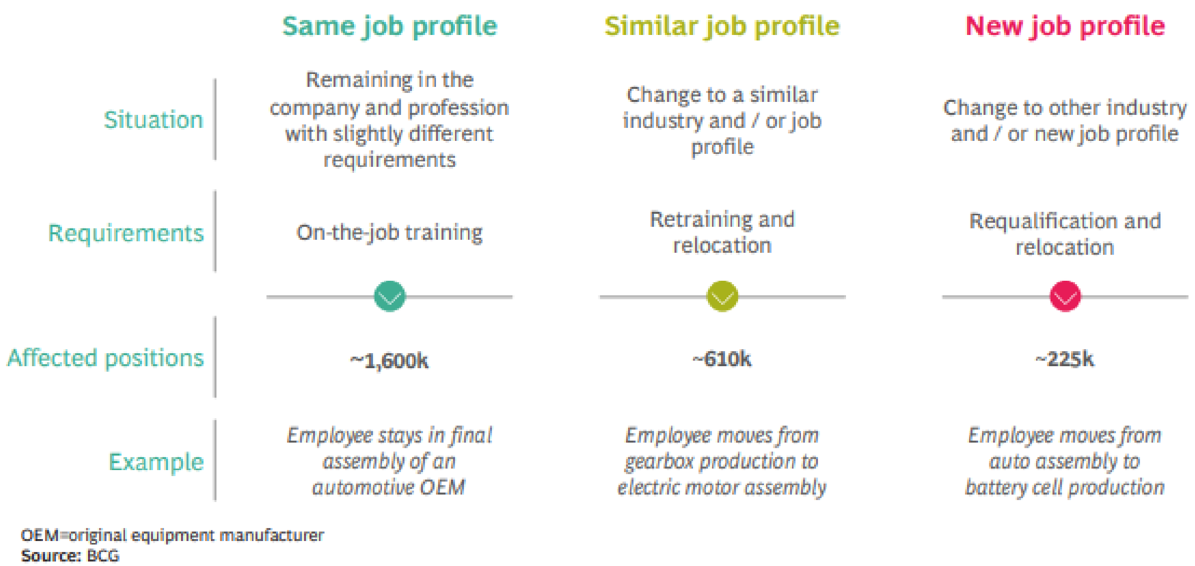

Figure 5: Positions with Dedicated Training Needs

In addition, the study provides an outlook on different trends influencing job losses and job gains across various industries.

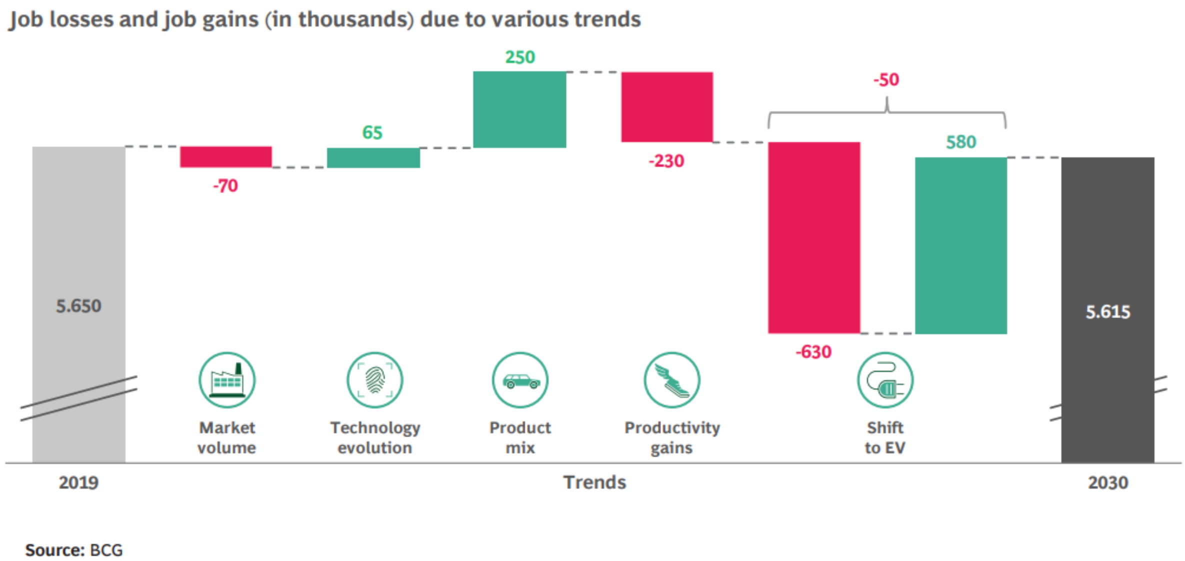

Figure 6: Trends Influence on Job Losses and Gains

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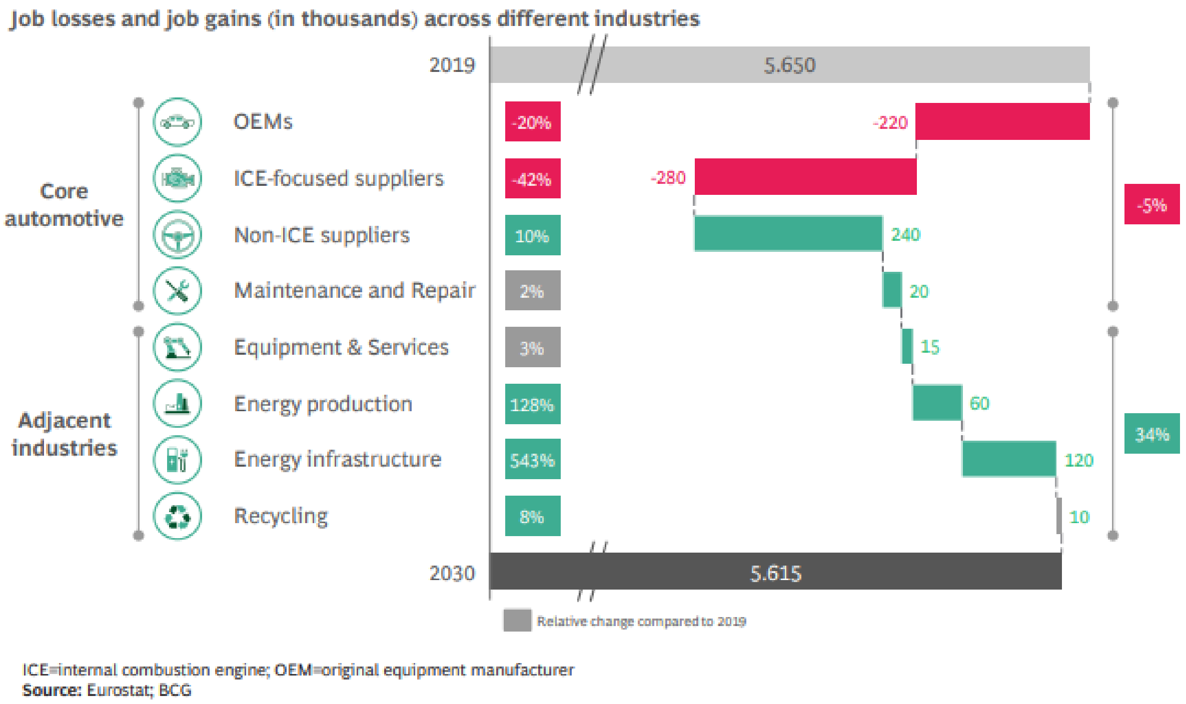

Figure 7: Decrease for Core and increase for Adjacent Industries

3.2.5 Ifo INSTITUT - The Importance of the Internal Combustion Engine in the Status Quo

The study[12] assesses the impact of the expected ban on internal combustion engines on employment and the economic performance of the German automotive industry. Some conclusions correspond to the time the study was created (2017 with datasets from 2010-2015) and do not correspond to the development of electromobility and energy in recent years.

The ICE ban (the study does not include a ban on vans, trucks and buses) will directly or indirectly affect approximately 10.2 % (min. 600,000) of jobs in the German manufacturing sector.

In terms of **company size**, the transition to electromobility will be a bigger problem for SMEs (more than 130,000 jobs, i.e. 21.3 % of the total affected).

Regarding **employment in car manufacturing**, 58 % of jobs will be affected (directly or indirectly) by the ICE ban.

[12] Prof. Dr. Dr. h.c. Clemens Fuest, ifo Institut, 9/17/2017, The Importance of the Internal Combustion Engine in the Status Quo – a Study

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The German car industry's high labour productivity and knowledge level will cause the ICE ban to have a more significant impact on GDP – the study estimates it at 12.8 %.

The expected ICE ban stimulates investment in alternative technologies, confirmed by Germany's significant share of international patents related to electromobility. This does not apply to the field of battery technology, where the USA and Japan are at the forefront. The critical areas for new jobs and skills are thus the **development and production of batteries** and **charging infrastructure**. The study assumes an annual increase of more than 3 million BEVs on German roads with a complete ban on ICE - with the estimated need of 1 charging point per 30 BEVs, this means a substantial burden on the charging and electrical distribution network. Additional electricity demand for 3 million BEV should increase annual German electricity demand by 1.1 % and its price by 0.5 %. This estimate is based on the assumption of sufficient production of "carbon neutral" clean electricity and a market model in 2017. Today, the situation is dramatically different - lower estimates of the increase in electricity consumption are +20 %. The study concludes that even under the assumed favourable conditions of electricity production, it does not consider the ICE ban to be the optimal transitional technological path to achieve environmental goals.

4 Skills Transition – Renewable Energy Sector

This section is based on the following studies[13, 14] and revolves around the renewable energy sector.

4.1 CURRENT SITUATION/RECENT DEVELOPMENTS WITH RENEWABLE ENERGY

The rapidly rising challenges of climate change reinforce the need for a just and inclusive transition toward a clean, reliable energy supply and decent and climate-friendly jobs. The transition was already underway as in 2021, the number of jobs in the renewable energy sector grew to 12.7 million with an upward trajectory since 2012 (according to IRENA), with photovoltaics having the highest share, around 4.29 million jobs.

Large-scale solar facilities feed power to the grid, while small, off-grid solar applications offer much-needed access to electricity to remote and energy-poor communities. Although off-grid sales took a hit from COVID-19 in 2020, off-grid solutions will continue to power farming, food processing, education and health care.

The following table outlines the number of jobs in specific renewable energy segments.

Table 4: Number of Jobs in Specific Renewable Energy Segments

SEGMENT	NUMBER OF JOBS IN MILLIONS (2021)
PHOTOVOLTAICS	4.29
BIOENERGY	3.44
HYDROPOWER	2.37
WIND ENERGY	1.37

[13] Renewable energy and jobs: Annual review 2022. Report: Renewable Energy and Jobs: Annual Review 2022. (2022, September 22). Retrieved November 20, 2022, from https://www.ilo.org/global/publications/books/WCMS_856649/lang--en/index.htm

[14] Renewable energy and jobs – annual review 2021. Special edition: Labour and Policy Perspectives: Renewable Energy and Jobs – Annual Review 2021. (2021, October 21). Retrieved November 20, 2022, from https://www.ilo.org/global/publications/books/WCMS_823807/lang--en/index.htm

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The wind sector's workforce is still male-dominated; only a fifth of workers are women, comparable to the traditional oil and gas industry. The renewable energy sector shows a better gender balance (32 % women).

The energy transition has revealed the need to expand skills in all regions to create a capable renewable energy workforce. Meeting that need will require more vocational training, more robust curricula and greater training of trainers. Using digital innovations in teaching is another task, especially concerning the pandemic.

Policy frameworks grounded in effective social dialogue must use labour market incentives to open new possibilities for workers who lose jobs in conventional energy, along with industrial and enterprise policies to leverage existing domestic industries. Social protection measures may be needed in the interim and subsequently.

The ILO tripartite *Guidelines for a just transition towards environmentally sustainable economies and societies for all* offer an essential framework to promote further decent work and social justice in the energy transition, addressing all aspects from quantity to quality employment.

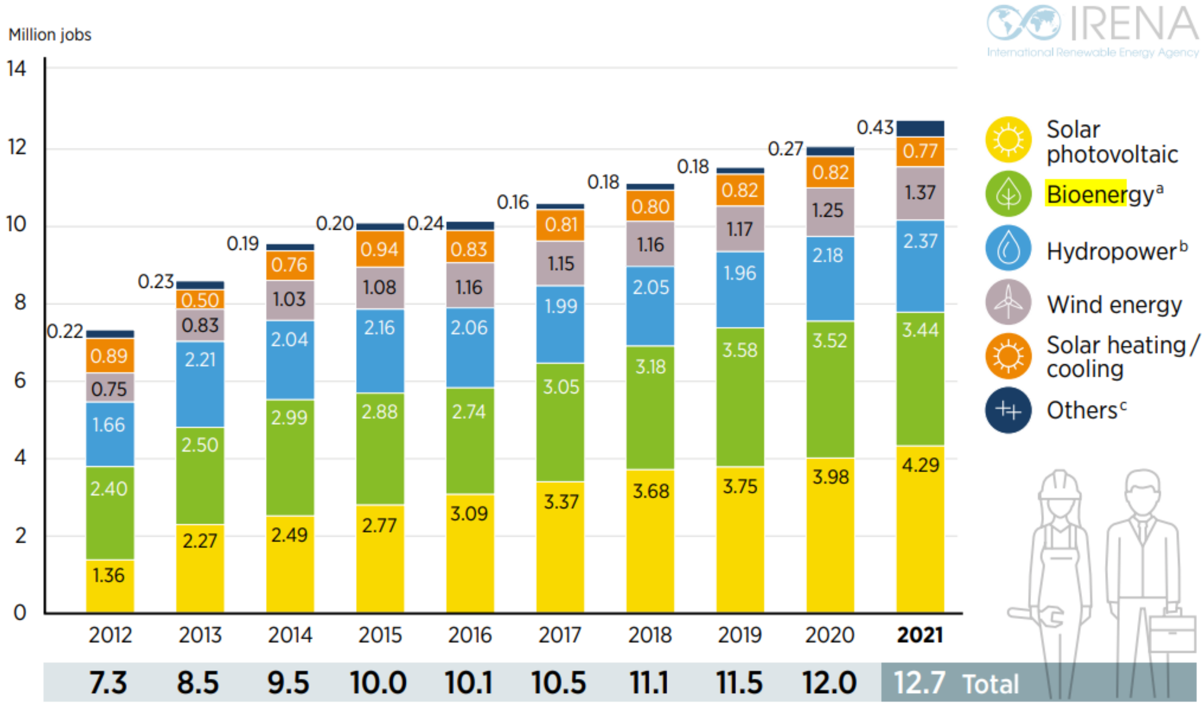
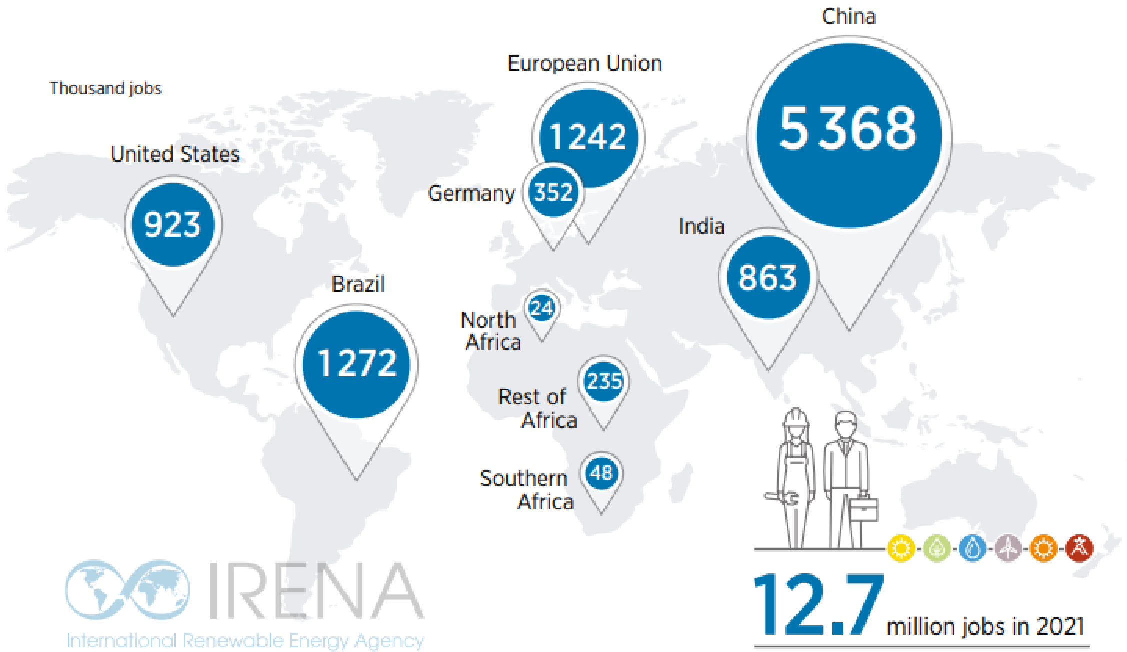


Figure 8: Global Renewable Energy Employment by Technology 2012-2021



Source: IRENA jobs database.

Disclaimer: This map is provided for illustration purposes only. Any boundaries and names shown do not imply any endorsement or acceptance by IRENA.

Figure 9: Renewable Energy Employment in Selected Countries

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	World	China	Brazil	India	United States	European Union (EU27)[o]
Solar PV	4 291[e]	2 682	115.2	217[h]	255[i]	235
Liquid biofuels	2 421	51	874.2[g]	35	322.6[j]	142
Hydropower[a]	2 370	872.3	176.9	414	72.4[k]	89
Wind power	1 371	654	63.8	35	120,2	298
Solar heating and cooling	769	636	42	19		19
Solid biomass[b, c]	716	190		58	46.3[l]	314
Biogas	307	145		85		64
Geothermal energy[b, d]	196	78.9			8[m]	60[d]
CSP	79	59.2				5.2
Total	12 677[f]	5 368	1 272	863	923[n]	1 242[f]

Note: The figures presented here are the result of a comprehensive review of primary national entities, such as ministries and statistical agencies, and secondary data sources, such as regional and global studies. Empty cells indicate that no estimate is available. Columns may not add up to totals due to rounding.

a. Direct jobs only.

b. Power and heat applications.

c. Traditional biomass not included.

d. Includes 7 400 jobs for ground-based heat pumps in EU countries.

e. Includes an estimate of 342 000 jobs in off-grid solar PV in South Asia and in East, West and Central Africa.

f. Includes 39 000 jobs in waste-to-energy.

g. Includes about 168 400 jobs in sugarcane cultivation and 167 800 in alcohol/ethanol processing in 2020, the most recent year for which data are available. Figure also includes a rough estimate of 200 000 indirect jobs in equipment manufacturing and 326 900 jobs in biodiesel in 2021.

h. Includes 137 000 jobs in grid-connected and 80 400 in off-grid solar PV. Also see note e.

i. Includes jobs in all solar technologies, principally PV but also solar heating and cooling and concentrated solar power.

j. Includes 258 700 jobs for ethanol and about 63 900 jobs for biodiesel in 2021.

k. US DOE (2022d) estimate, including 53 029 jobs in traditional hydro and 11 485 jobs in low-impact hydro. An estimated 7 901 jobs in pumped hydro (energy storage) are not included in the US total.

l. Includes woody biomass fuels (33 898 jobs) and biomass power (12 388 jobs).

m. Figure is for direct geothermal power employment.

n. Includes 98 932 jobs in technologies not separately broken out in the table, such as solar heating and cooling, geothermal heat, heat pumps and others. Solar heating and cooling are also included (but not reported separately) in the Solar Foundation's estimate for all solar technologies, so there is a small amount of double counting.

o. Solar PV and wind jobs are for 2021; hydropower figures for 2020 and 2021; other technologies are for 2020.

Source: IRENA jobs database.

Figure 10: Estimated Number of Jobs in Renewable Energy in Selected Countries (2019-20)

4.2 EUROPE

Countries in Europe hosted a combined total of 1.5 million renewable energy jobs, approximately 1.2 million in EU member countries (the EU-27, following Brexit). The bioenergy sector is the largest renewable energy employer on the continent. Solid biomass (for heat and

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electricity) leads with approximately 360,000 jobs, followed by biofuels, with 155,000 jobs, and biogas, with 67,000 jobs.

4.2.1 Wind

European wind power employment is at 351,500, with 297,600 jobs in EU member states.

- The continent's cumulative wind-generating capacity stood at 222 GW in 2021. Some 14.2 GW were newly added.
- Germany, Spain and the United Kingdom are the leaders in overall installations in Europe, but in all three countries, the pace slowed considerably in 2020
- The European offshore wind industry continues to expand, and GWEC estimates that nearly 100,000 jobs have been created in this segment.

4.2.2 Solar PV

Europe and the EU member states added record amounts of solar PV in 2019 and 2020, more than double the volume in 2018 (IRENA, 2021a), defying worries that COVID-19 could shrink the market. EU members comprise 90 % of the continent's capacity additions, up from 79 % in 2019. IRENA estimates solar PV employment in all of Europe at 292,000 jobs in 2021; for the European Union, the estimate is 235,000.

4.3 EMPLOYMENT TRENDS AND THE 4 DIMENSIONS OF MISALIGNMENT

A multitude of factors shapes employment trends (see Figure 11).

- Key among them is the rate at which renewable energy equipment is manufactured, installed and put to use (primarily a function of costs and overall investments).
- Costs, especially for solar and wind technologies, continue to decline. With relatively steady annual investments, lower costs have translated into broader deployment.
- Investments would boost future job creation, even allowing for growing labour productivity.
- Policy guidance and support remain indispensable for establishing overall renewable energy roadmaps, driving ambition, and encouraging the adoption of transparent and consistent rules for feed-in tariffs, auctions, tax incentives, subsidies, permitting procedures and other regulations.

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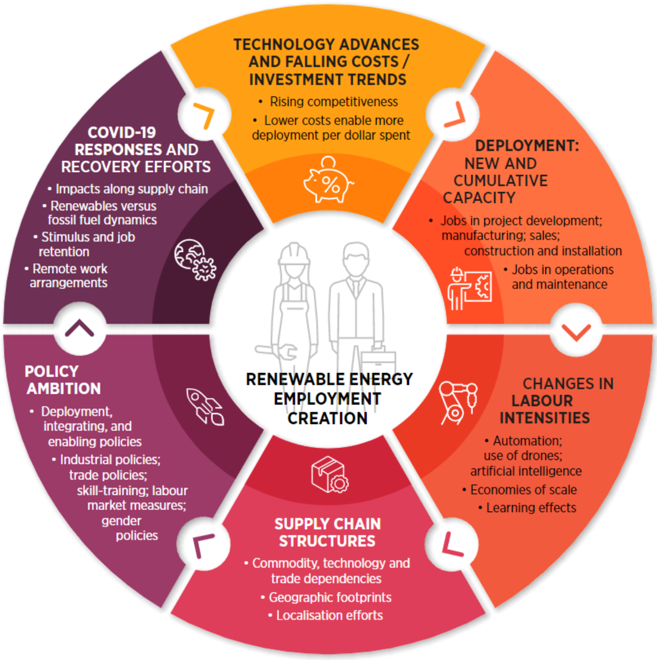

Figure 11: Factors Influencing the Renewable Energy Sector

4.3.1 The four dimensions of misalignment & Energy transition and policy intervention and guidance

As with any transition, the energy transition cannot be expected to proceed smoothly without appropriate policy intervention and guidance. Analysis by IRENA (2020c) and by ILO (2019a) has shown that the energy transition will encounter frictions and misalignments in several dimensions, such as time, space, education and economic structure, with skills gaps emerging.

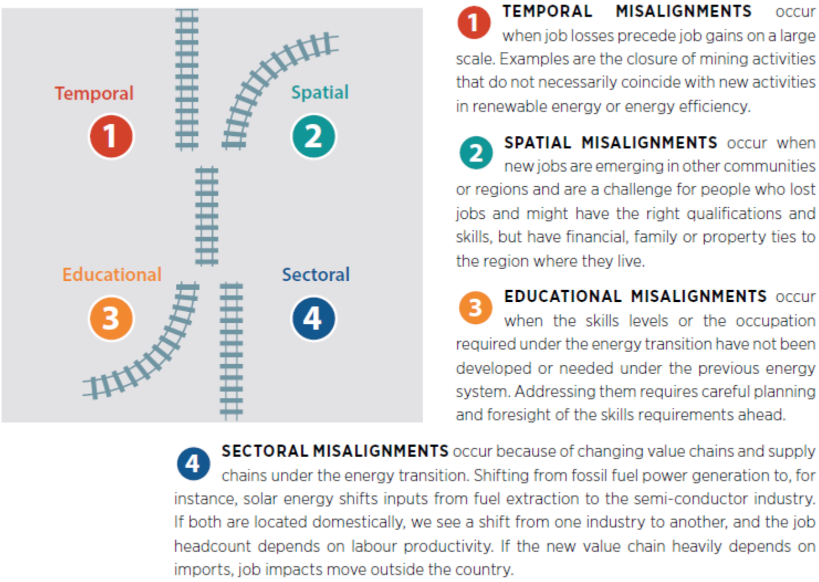

Figure 12: Types of Misalignments

4.4 FUTURE PROJECTIONS

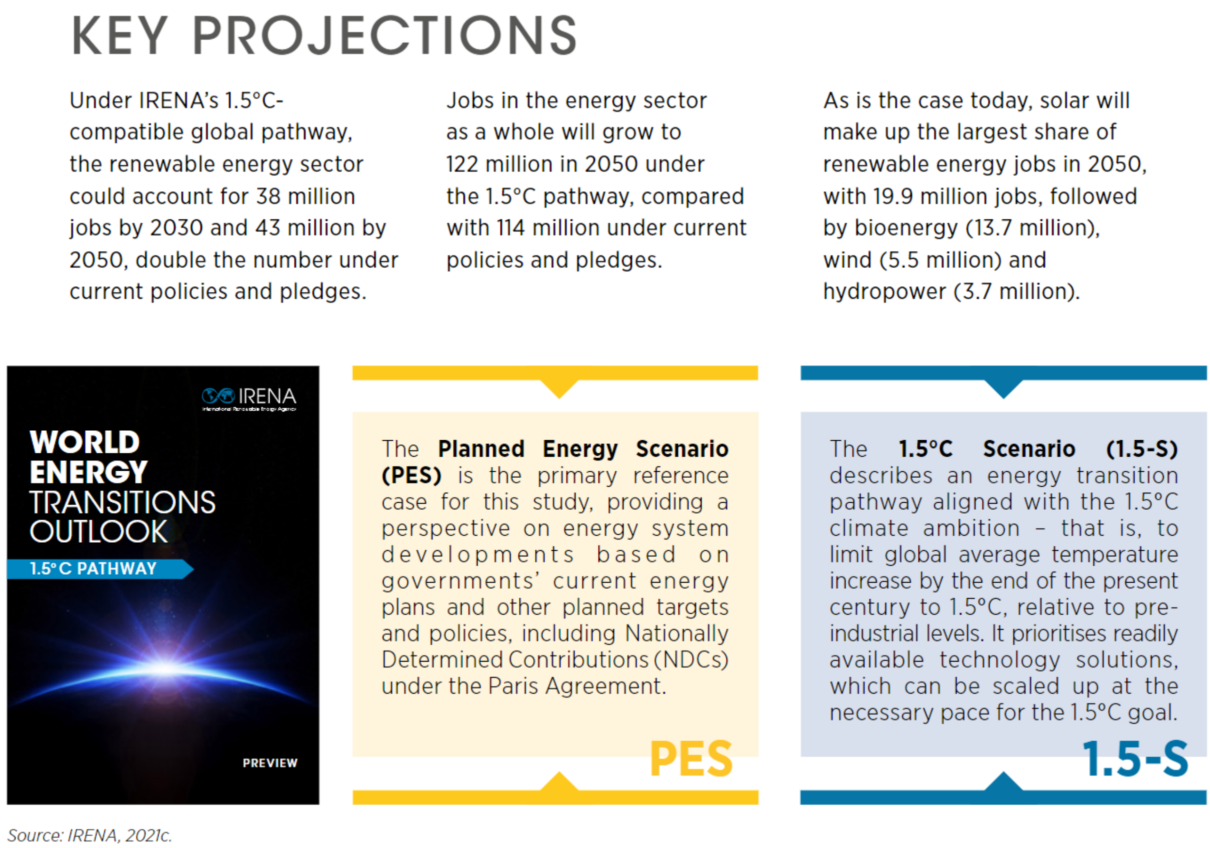

Figure 13: Future Projections and Scenarios (PES and 1.5 -S)

By 2030 38 million people will be working in the renewable energy sector. The 1.5 °C pathway put forward by the International Renewable Energy Agency (IRENA) in its World Energy Transitions Outlook will lead to 122 million energy sector jobs globally **by 2050** (compared with 114 million under current policies and pledges) of which 43 million will be in renewables.

Solar photovoltaics will provide the most jobs by 2050 (20 million), followed by bioenergy, wind and hydropower.

IRENA's World Energy Transitions Outlook is a broad set of fiscal policy measures, such as adequate carbon pricing of emissions across sectors. Additionally, subsidies and public investment in infrastructure are needed, as well as expenditures to support a just energy transition and address social challenges. It also highlights the critical role of international cooperation in fostering economic diversification, supporting a just transition specifically in fossil-fuel-dependent countries, and enabling developing countries to leapfrog to modern and sustainable energy systems and harness the benefits of the energy transition.

POWER GRIDS AND ENERGY FLEXIBILITY - will be the backbone of the energy transition. Almost three times as many people as today will work in this sector, bringing employment to 21 million by 2030 and nearly 25 million by 2050 under the 1.5 °C Scenario. Grid enhancement and flexibility options matter more under the 1.5 °C Scenario as the system's complexity grows. Compared with the PES, 1.5 times as many people would be employed by 2050.

KEY PROJECTIONS

Under IRENA's 1.5°C-compatible global pathway, the renewable energy sector could account for 38 million jobs by 2030 and 43 million by 2050, double the number under current policies and pledges.

Jobs in the energy sector as a whole will grow to 122 million in 2050 under the 1.5°C pathway, compared with 114 million under current policies and pledges.

As is the case today, solar will make up the largest share of renewable energy jobs in 2050, with 19.9 million jobs, followed by bioenergy (13.7 million), wind (5.5 million) and hydropower (3.7 million).

			2030	2050
Renewable energy	Absolute	million jobs	37.8	43.4
	DIfference with the PES	million jobs	19.8	20.8
		relative	110%	92.8%

Source: IRENA, 2021c.

Figure 14: Renewable Energy Jobs Worldwide per Scenario

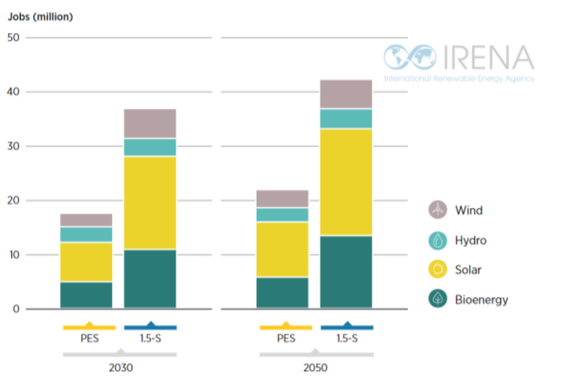

Figure 15: Jobs in Renewable Energy, by Technology, in the 1.5 C Scenario and PES, 2030 and 2050

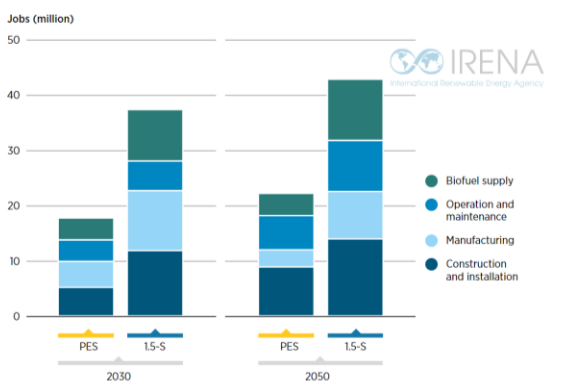

Figure 16: Renewable Energy Jobs, by segment of value chain, in the 1.5 C Scenario and PES, 2030 and 2050.

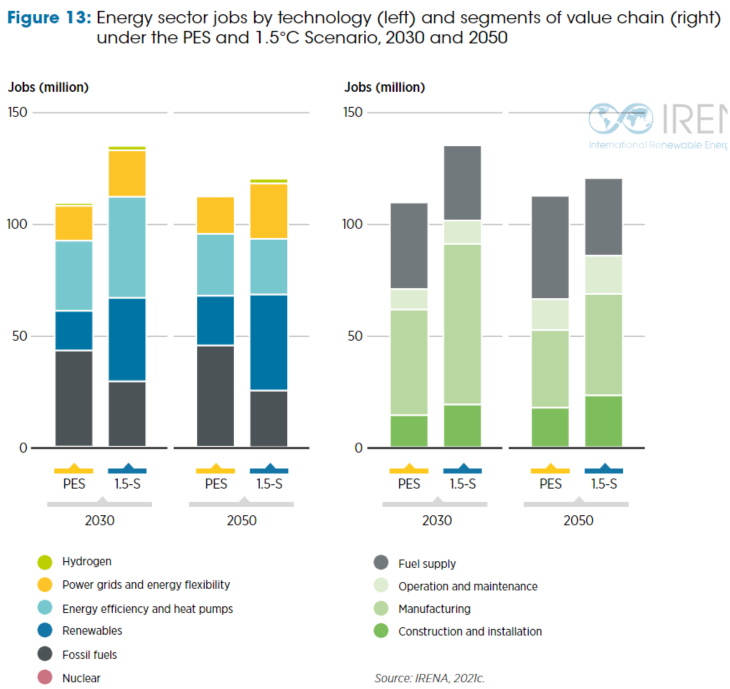

Figure 17: Energy Sector Jobs by Technology (left) and Segment of Value Chain (right) under the PES and 1.5 °C Scenario, 2030 and 2050.

4.5 IMPLICATIONS ON BATTERIES AND BEYOND

The global capacity to manufacture lithium-ion battery cells for automotive and stationary storage **grew seven-fold** in the decade to 2020. China holds 78 % of that capacity, with much smaller shares in Japan and the Republic of Korea (both of which, like China, were able to draw on their existing consumer battery manufacturing base) and in Europe and the United States. Including new plants under construction or announced, **worldwide capacity may quadruple by 2025**, with 64 % of the total in China, 23 % in Europe and 6 % in the United States (BNEF, 2021c).

Employment in the manufacturing of cells and their key components is thus highly concentrated geographically. This is also true for the **essential metals used**. A large share of lithium mining occurs in Australia, Chile and China; cobalt mining in the Democratic Republic of Congo; and nickel mining in Russia, Canada, Australia and a few other countries. Except for nickel, China leads in refining these metals. As a dominant producer of components for batteries and by far the largest market for electric cars and buses, China claims the bulk of related employment. In addition to demand-side policies (like subsidies for purchases of electric vehicles), industrial policy measures were vital to China's success. Those policies included targets, incentives, government guarantees, public procurement programmes, research and development funding, and efforts to build up expertise in the electric vehicle and battery supply chain while shielding local manufacturers from the competition. Expanding the battery sector – and basing it mainly on recycling critical metals like cobalt and nickel – could be a source of large-scale employment.

According to the World Economic Forum and Global Battery Alliance (2019), “**a circular battery value chain**" could create **10 million jobs worldwide by 2030**. A few closely related technologies are of rising importance, notable batteries for energy storage, electric vehicles, and **"green" hydrogen**. These appear to expand significantly in the coming years as vehicle technology shifts from internal combustion engines to electric motors. Grid transmission and distribution networks will be essential in expanding these technologies. Still, not all associated jobs can be counted as transition-related, given that the energy system is still centred firmly on fossil fuels, especially for transport.

A comprehensive accounting of employment impacts of the energy transition should include jobs in industries that cannot be considered "green" in their own right, including mined materials needed for renewable energy equipment such as nickel and lithium for batteries and inputs from energy-intensive industries such as aluminium, steel or concrete (for wind, solar and other renewable energy installations). Coal sector mining and related job losses can be potentially decreased due to the reorientation of the minerals needed for batteries.

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5 Recommendations

The following recommendations were drawn in the studied literature and materials.

- A green transition that works for the environment, industry, and workers – to provide a platform for a discussion with stakeholders and to support them to access the needed funding and skilled workforce to manage the transition.
- Promote the development of skills in digital, software and electrical engineering and increase access to skills across the EU
- Attracting foreign direct investments into the battery value chains is the key ingredient to support this transition
- Strategic e-mobility communication should be strengthened
- Strong governmental support towards battery production
- There is a need to create a conceptual framework for skills transfer and use
- When building the gigafactory, the requalification of current and upskilling of future employees needs to be supported by government, private sector, as well as education sector. In addition, the adjacent jobs and spill-over effect between the automotive industry and energy sector must be navigated conjointly.
- This transition will also bring new jobs connected to e-mobility infrastructure, such as charging or manufacturing of charging stations
- There is a need to of stakeholder readiness synchronisation when it comes to the speed of the transition - This could be achieved through tight cooperation of the public and private sector, as well as other relevant stakeholders, including the non-governmental sector.
- When it comes to tackling the transition, the following gaps needs to be filled:
    - Geographical gap – transition will hit different regions differently
    - Skills gap – to fill the gap between the workers of today and tomorrow
    - Time gap – to compensate the different speed of the transition
    - Attractiveness gap – to make new job as attractive as possible for the potential workers

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- There is a need of policies that will support the transition in terms of
  - Processes for industrial transformation – in a broader sense not to cover only automotive industry
  - Regional development – regional plans need to accommodate different needs among different regions
  - Labour market and social protection schemes – company-specific plans for re-skilling of workers as well as retirement schemes or unemployment benefits
  - Stakeholder participation – at every level

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