The economic opportunity of AI in Luxembourg

Capturing the next wave of benefits from *generative* AI

An Implement Consulting Group study commissioned by Google

May 2024

The economic potential of AI can be boosted further by generative AI

IM

To capture the next wave of AI benefits across society, Luxembourg needs to promote innovation, invest in skills and ensure clear rules.

The economic opportunity

Generative AI technology is developing faster than previously anticipated, and the peak economic contribution could come sooner than expected, in as little as ten years.

In the peak year, generative AI alone could boost Luxembourg's GDP by

€6-8 billion

→

+9% GDP
annual contribution in the peak year if Luxembourg achieves widespread adoption.

Gains come from three sources …

Productivity boost from people working with generative AI.

Freed-up time when generative AI helps to automate our work.

Re-prioritised and re-employed time for other value-creating activities.

The job implications

72% of jobs in Luxembourg are estimated to work **together with** generative AI.

75% of workers in Luxembourg believe that generative AI will help them become more **productive.**

Share of jobs exposed to automation by generative AI
% of total employment at workplaces in Luxembourg

515,000 jobs[1]

22%	→ No automation
72%	→ AI as a complement
6%	→ Partial or full displacement

Luxembourg is well placed to manage the job changes from generative AI.

New jobs in the AI-powered economy are expected to replace those lost due to automation, resulting in unchanged employment levels. The highly exposed jobs represent around 7-10% of the expected future level of job changes in Luxembourg.

The transition is expected to be gradual, allowing workers time to adapt to new tasks and develop new skills.

1) This includes cross-border workers residing in Germany, Belgium and France, who make up almost half of the total of 515,000 jobs.
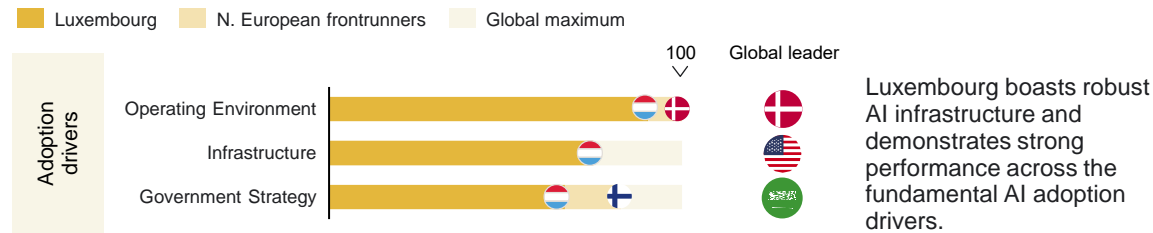
Luxembourg can leverage its strong position on fundamental AI adoption drivers but needs more talent and innovation to capture the potential
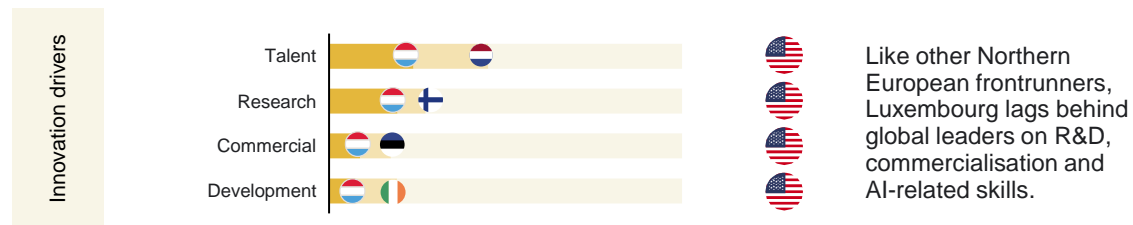
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AI readiness in Luxembourg

Luxembourg performs well on basic AI adoption drivers like other small, digitally advanced European economies …

Luxembourg's AI capacity according to the Tortoise Global AI Index

Global AI Index, score out of 100 (global leader)

Luxembourg   N. European frontrunners   Global maximum

Luxembourg boasts robust AI infrastructure and demonstrates strong performance across the fundamental AI adoption drivers.

… but lags behind global leaders on innovation drivers

Like other Northern European frontrunners, Luxembourg lags behind global leaders on R&D, commercialisation and AI-related skills.

Conclusions and policy implications

Generative AI can boost future economic growth in Luxembourg, exceeding current long-term GDP forecasts. Leading banks are raising growth forecasts from as early as 2028 due to the new expectations for generative AI.

The 9% boost to GDP over ten years assumes that Luxembourg captures the full value of AI without delay.

A five-year delay in the adoption and development of generative AI could reduce potential GDP gains in Luxembourg from 9% to 2%, reducing the potential over ten years from €6-8 billion to €1-2 billion.

Capturing the full economic gains requires skills, innovation and a conducive regulatory framework.
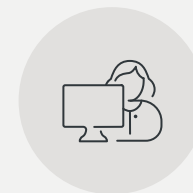
Retrain and upskill workforce

Grow R&D by local innovators

Accelerate commercial uptake

Note: The Tortoise Global AI Index is underpinned by 111 indicators collected from 28 different public and private data sources and 62 governments. Northern European frontrunners refers to nine European countries comparable to Luxembourg in terms of size and level of digitalisation.
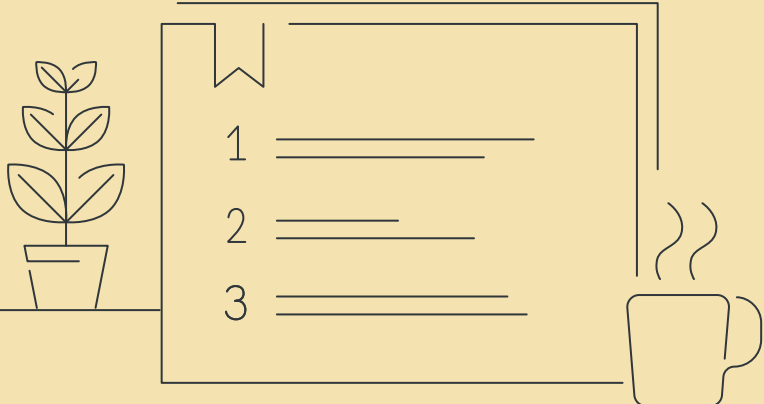
Foreword

Making AI benefit society as a whole requires an adaptive, human-centric and trustworthy approach

AI and the next wave of generative AI have the potential to be the most powerful technology in decades. Responsible AI can help solve global challenges like climate change and access to quality medical care.

AI can make countries more prosperous, productive, innovative, creative and secure. At the same time, there are plenty of pitfalls, paradoxes and tensions that decision-makers will need to navigate.

AI has evolved rapidly with the breakthrough of generative AI in 2022 and its fast adoption in 2023. This report estimates the economic potential of generative AI while recognising the significant economic potential of other types of AI.
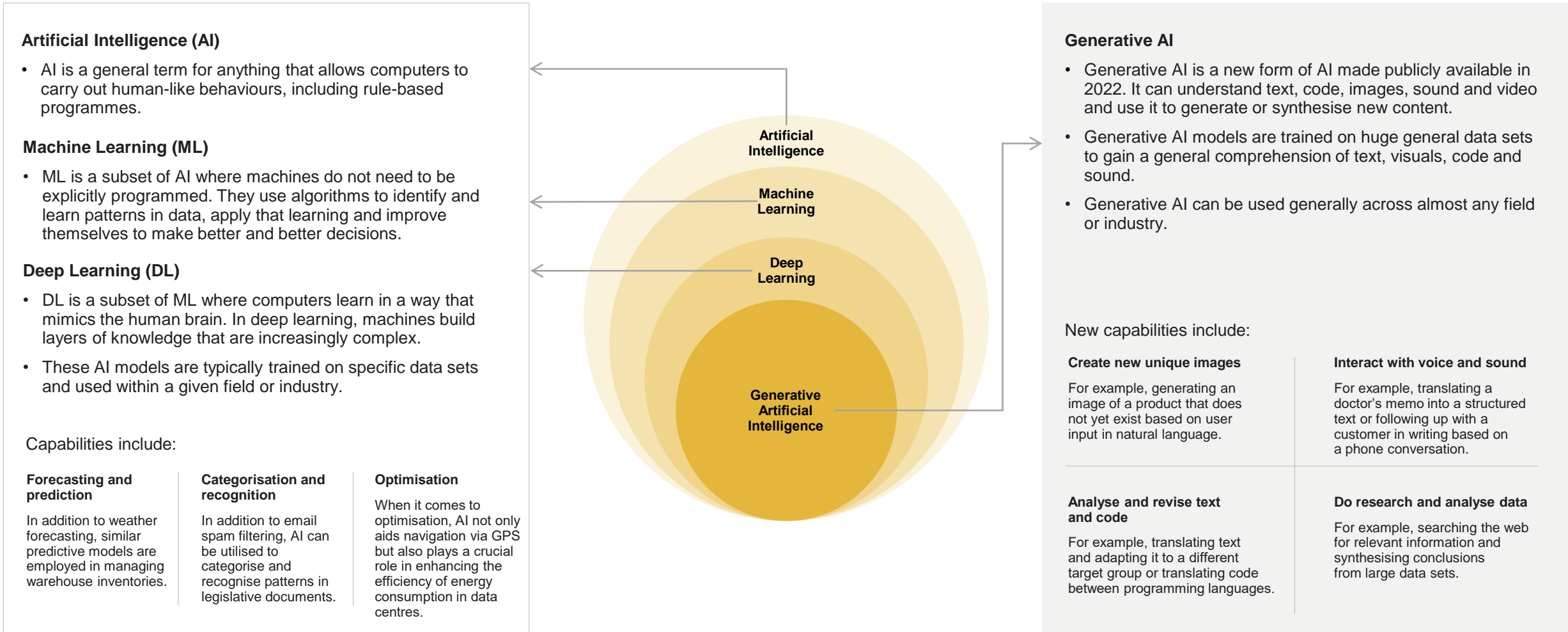
Contents

01

Introduction to AI

This report covers all types of AI with a particular focus on generative AI.

AI can help humans solve tasks faster and better – and with generative AI, machines can now understand and interact in language, sound and images

Artificial Intelligence (AI)

- AI is a general term for anything that allows computers to carry out human-like behaviours, including rule-based programmes.

Machine Learning (ML)

- ML is a subset of AI where machines do not need to be explicitly programmed. They use algorithms to identify and learn patterns in data, apply that learning and improve themselves to make better and better decisions.

Deep Learning (DL)

- DL is a subset of ML where computers learn in a way that mimics the human brain. In deep learning, machines build layers of knowledge that are increasingly complex.

- These AI models are typically trained on specific data sets and used within a given field or industry.

Capabilities include:

Forecasting and prediction

In addition to weather forecasting, similar predictive models are employed in managing warehouse inventories.

Categorisation and recognition

In addition to email spam filtering, AI can be utilised to categorise and recognise patterns in legislative documents.

Optimisation

When it comes to optimisation, AI not only aids navigation via GPS but also plays a crucial role in enhancing the efficiency of energy consumption in data centres.

Artificial Intelligence

Machine Learning

Deep Learning

Generative Artificial Intelligence

Generative AI

- Generative AI is a new form of AI made publicly available in 2022. It can understand text, code, images, sound and video and use it to generate or synthesise new content.

- Generative AI models are trained on huge general data sets to gain a general comprehension of text, visuals, code and sound.

- Generative AI can be used generally across almost any field or industry.

New capabilities include:

Create new unique images

For example, generating an image of a product that does not yet exist based on user input in natural language.

Interact with voice and sound

For example, translating a doctor's memo into a structured text or following up with a customer in writing based on a phone conversation.

Analyse and revise text and code

For example, translating text and adapting it to a different target group or translating code between programming languages.

Do research and analyse data

For example, searching the web for relevant information and synthesising conclusions from large data sets.
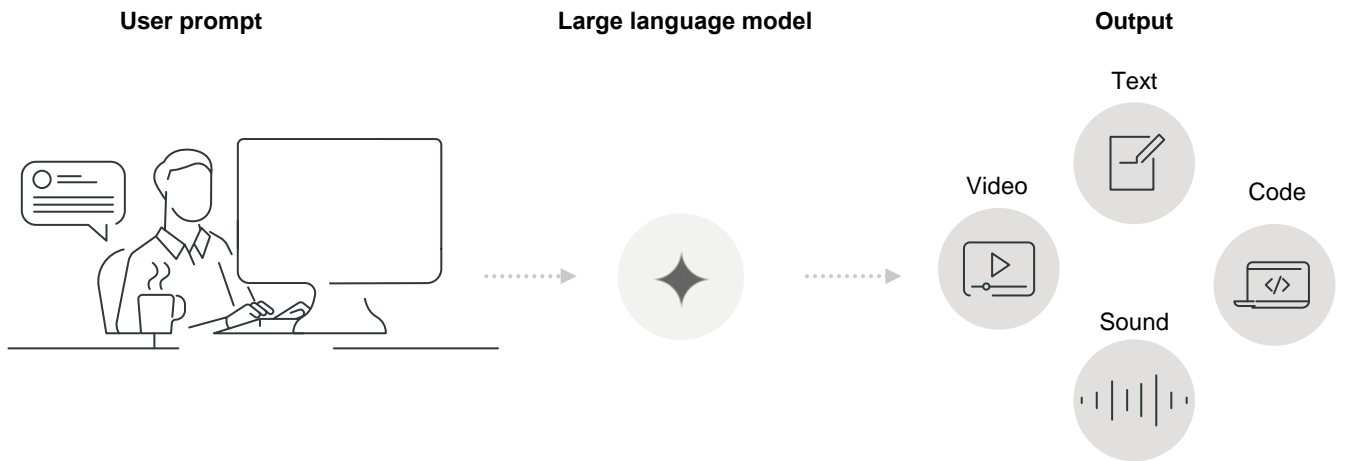

Note: An algorithm is a detailed set of instructions that a computer follows to carry out a task or solve a problem.
Source: Implement Economics based on expert interviews.

Recent developments have increased the capabilities and availability of AI models and have accelerated uptake

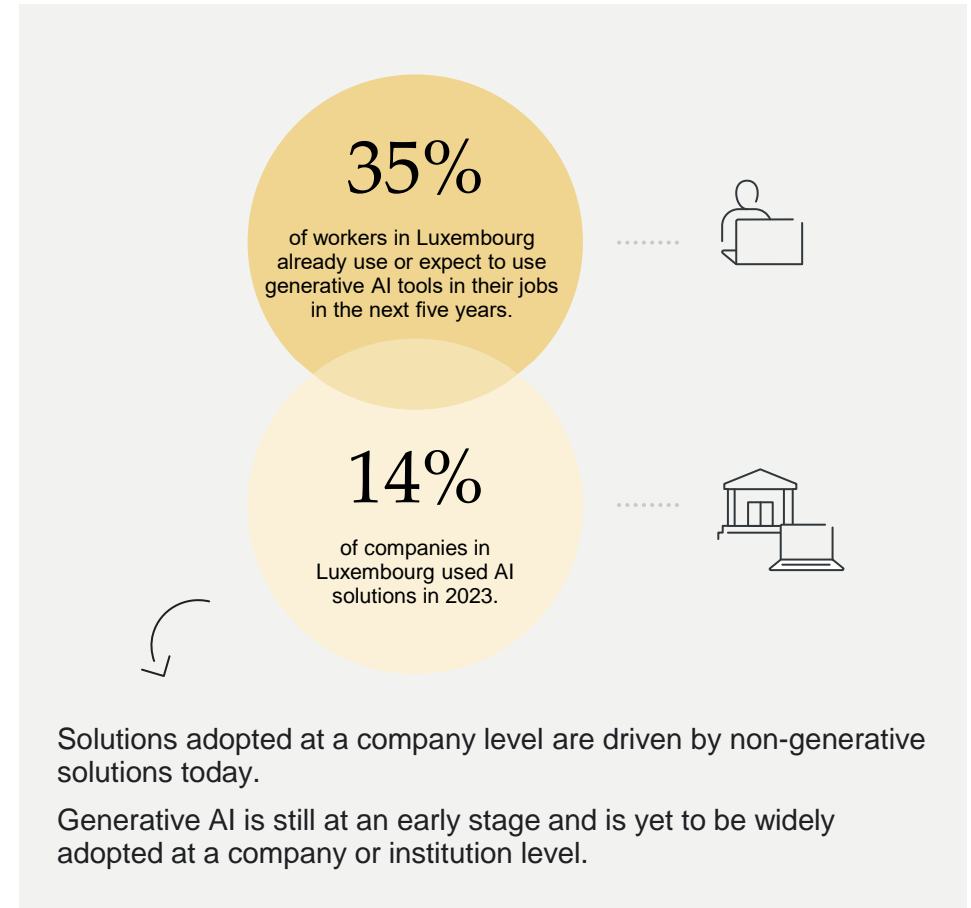## Generative AI models have strong built-in capabilities and are easy to work with …

User prompt

Large language model

Output

Text

Video

Code

Sound

No or low data requirements

Generative AI models are already trained on huge data sets. This makes them readily available for many tasks without any further data needed.

Easy to use in plain language

Generative AI models can be operated using ordinary language and do not require any specific coding skills to use.

Many models are online and free of charge

Several high-performing generative AI models are available online and do not require local ML setups or infrastructure to use.

… and many users have already adopted the technology

35%

of workers in Luxembourg already use or expect to use generative AI tools in their jobs in the next five years.

14%

of companies in Luxembourg used AI solutions in 2023.

Solutions adopted at a company level are driven by non-generative solutions today.

Generative AI is still at an early stage and is yet to be widely adopted at a company or institution level.

Source: Implement Economics based on the European Commission and Public First survey.

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Leveraging the full potential of AI will require further research, development and innovation

AI capabilities and requirements by level of development

	Organisational ML-based AI	Generic pre-trained models used online	Adaption of pre-trained models using APIs	Specialised fine-tuned models	Foundation models
Solvable tasks	Specific	General	General and moderately specialised	General and specialised	Most
Example	*E.g. detection of flawed products in manufacturing*	*Online chatbots, e.g. Gemini or ChatGPT*	*Organisation-level automation solution, e.g. auto-replies*	*Pre-trained model like Llama trained further on context-specific data*	*Model trained from the ground on new data, e.g. BLOOM*
Requirements					
Competences for use	●	○	◔	◔	◔
Competences for integrating solution	◔	◔	◔	◔	●
Data and infrastructure	◑	○	◔	◔	●
	Pre-2022	Current fast-adopting models	Next level of adoption	Only adopted by few frontrunner organisations	New frontier of AI

- Generative AI is still in its early phase using generic pre-trained models.
- Future value creation from AI requires more advanced models than the pre-trained models that are available online today.
- Leveraging the full potential of AI technology requires more advanced and specialised models.
- This requires new organisational skills, more data, more computing power and better infrastructure.

Figure explanation

○ No requirements

● Highest requirements

Note: Training or fine-tuning generative AI models generally requires significantly more computational resources compared to classic machine learning training.
Source: Implement Economics based on OECD.

02

Economic opportunities from AI

The main economic opportunity in Luxembourg arises from humans working together with generative AI.

AI has great economic potential which can be further boosted by generative AI

How to think about generative AI:
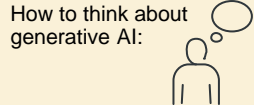
"What would you do if you had 1,000 well-trained interns ready to work for you day and night?"

AI can increase productivity

Academic studies conclude that labour productivity typically increases by 2-3 percentage points per year after firm-level AI adoption. The studies have been carried out on early adopters of AI technology and, as such, cannot be extrapolated to the general effects of AI on productivity.

Growth in labour productivity from AI adoption
Percentage points

6.8%

3.2%

2.7%

2.0%   2.2%

Acemoglu et al. (2022) | Zhai and Liu (2023) | Rammer, Fernández, and Czarnitzki (2022) | Damioli, Roy, and Vertesy (2022) | Alderucci et al. (2020)
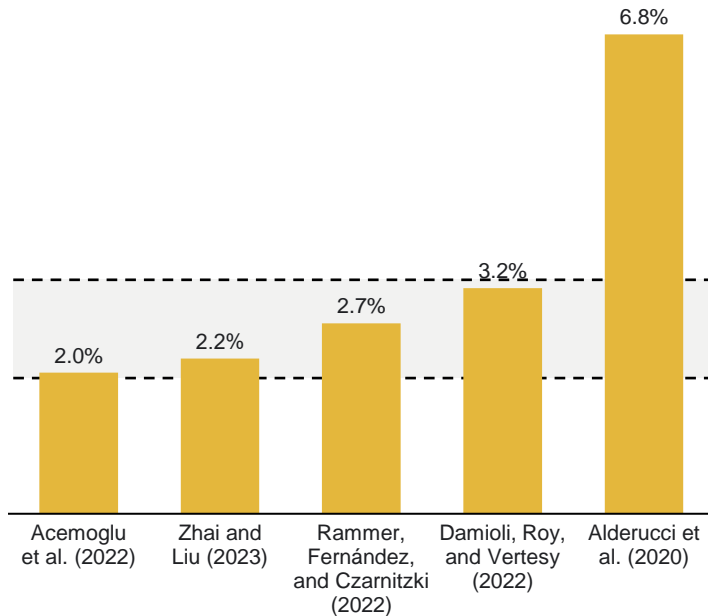
Generative AI advances automation

Generative AI can advance automation by nearly a decade because it is easier to use for individuals and organisations. However, significant uncertainty about adoption rates and speed of realisation of its benefits remain.

Automation potential
Adoption of AI technology

— With generative AI
— Without generative AI

2020 2025 2030 2035 2040 2045 2050
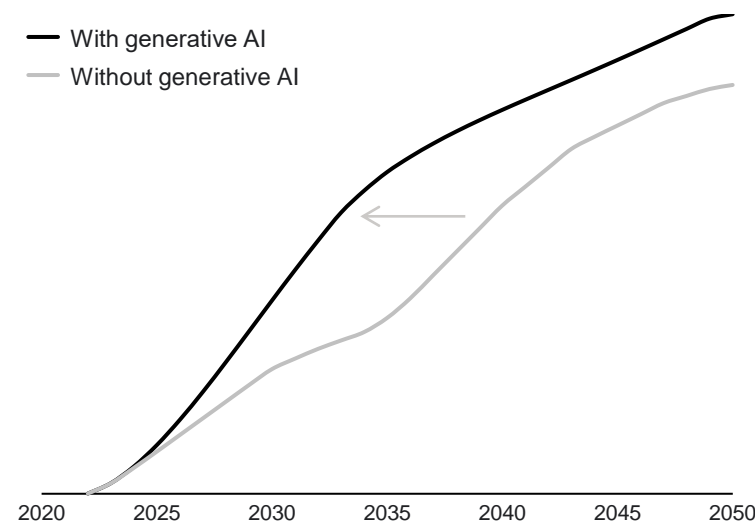
- AI has evolved rapidly with the recent breakthrough of generative AI. Due to its user-friendly nature, generative AI is expected to greatly accelerate the potential of AI to create economic impacts.

- Generative AI is only a part of AI's overall economic potential. Some studies estimate with some uncertainty that generative AI accounts for around one-third of the total effect of AI.

- This report estimates the macroeconomic potential of generative AI while recognising the significant economic potential of other types of AI.

Generative AI could increase Luxembourg's GDP by 9% in ten years

Potential impact of generative AI on GDP in Luxembourg
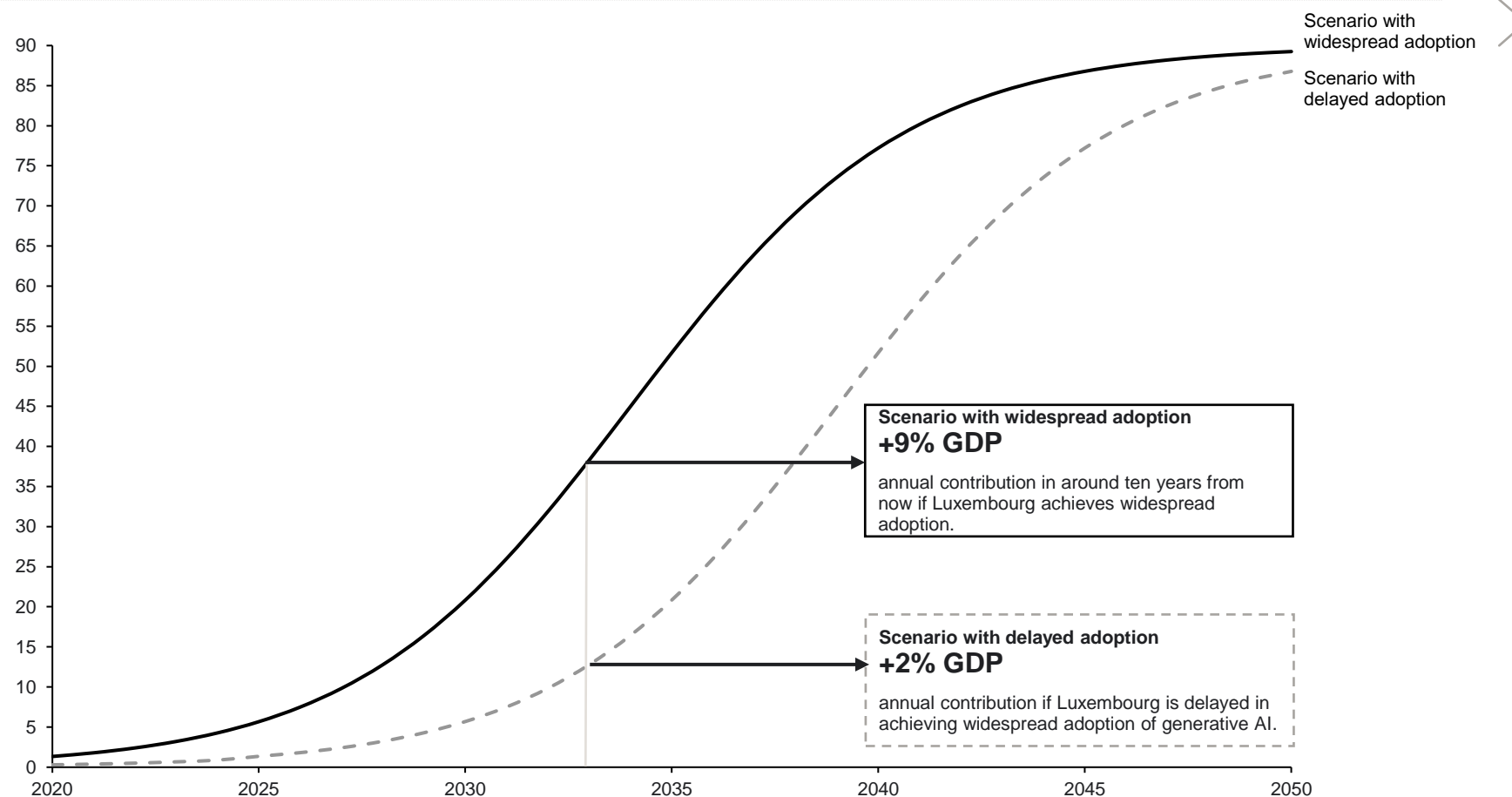€ billion increase from baseline GDP after a ten-year adoption period

5.5-6.5 — Productivity boost

1.0-1.5 — Re-employment

Productivity losses from re-employment of workers are estimated to reduce the GDP boost by up to €0.5 billion

6.0-8.0 — GDP increase

Productivity loss from re-employment

+9% GDP

if Luxembourg achieves widespread adoption within ten years.
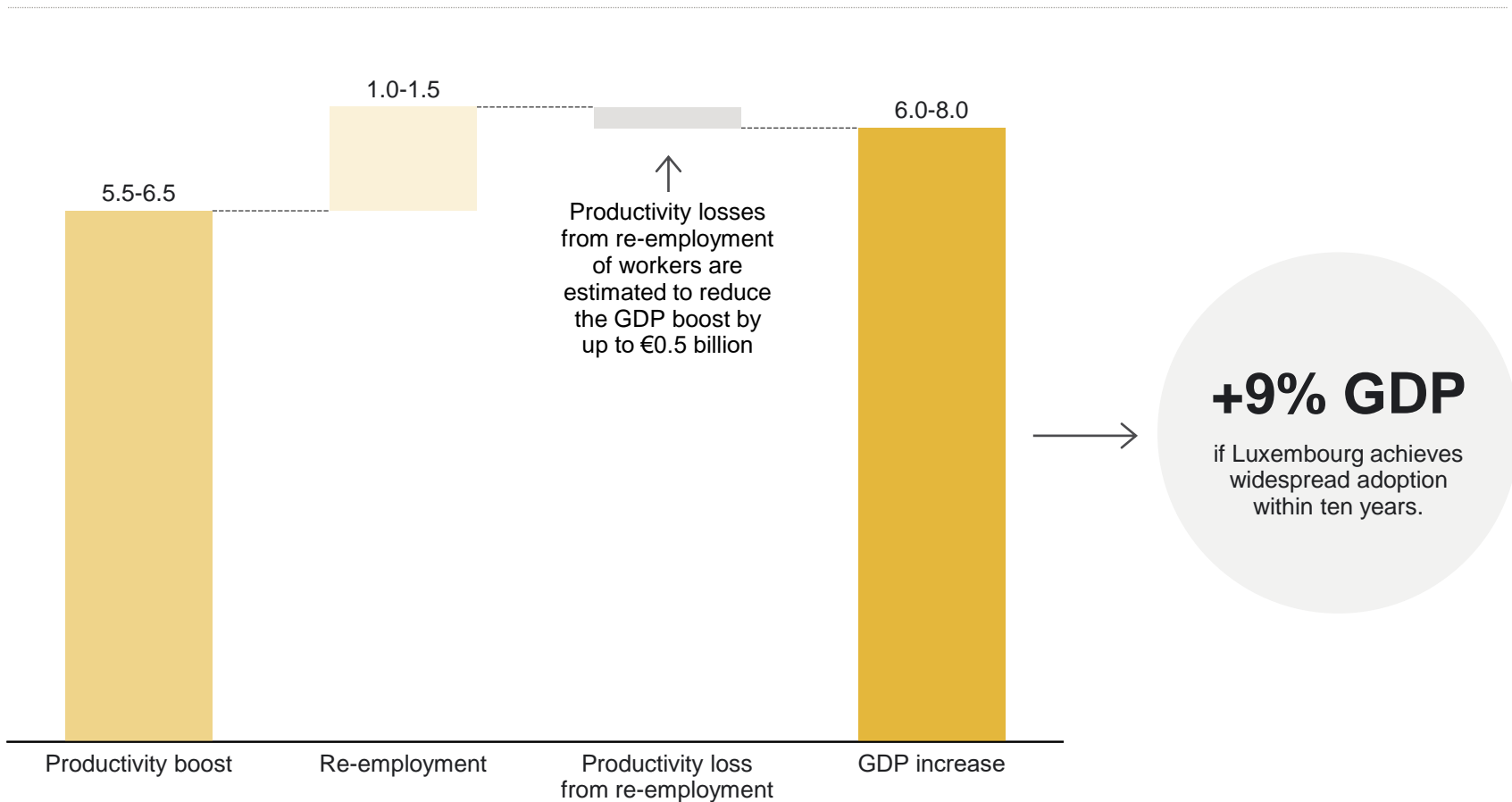
- If Luxembourg widely adopts generative AI, we estimate a potential increase in GDP of €6-8 billion over the next ten years.

- The dominant impact of generative AI is a productivity boost to the majority of workers (72%) by augmenting their capabilities, quality and efficiency, which is estimated at €5.5-6.5 billion for Luxembourg.

- The estimate includes impacts of re-employment of a small share of workers (6%), where generative AI is freeing up a significant share of work for other tasks. This is estimated at €1.0-1.5 billion in Luxembourg.

- The estimate accounts for the possible productivity loss associated with re-employment to other occupations. This reduces the estimate for Luxembourg by up to €0.5 billion.

- At its peak, the productivity effect of generative AI in Luxembourg is estimated to be equivalent to 1.6% annually.

- Generative AI is so powerful that Luxembourg's future economic growth could exceed current long-term GDP forecasts, and leading banks are raising growth forecasts from as early as 2028.

Note: The estimate assumes widespread adoption of generative AI over a ten-year period. There is much uncertainty around the capability and adoption timeline of generative AI. The size of the productivity boost depends on the difficulty level of tasks that generative AI will be able to complete and the number of jobs it can automate. GDP is in 2022 levels. The average number of work activities that potentially can be performed by generative AI across all types of tasks for both complemented and highly exposed workers corresponds to 20-25%. Our estimate is the isolated potential of generative AI. The estimated boost from generative AI may not be fully additive to GDP trends, as the GDP forecast already assumes a growth contribution from new technologies and generative AI may substitute some of that. Also, the boost from generative AI may be partially offset by an underlying growth slowdown.
Source: Implement Economics based on Eurostat, Statistiques.lu, O*Net, Briggs and Kodnani (2023a), BNP Paribas (2023), and Dell'Acqua et al. (2023).

A five-year delay in the adoption of generative AI could reduce Luxembourg's potential GDP gains from 9% to 2%
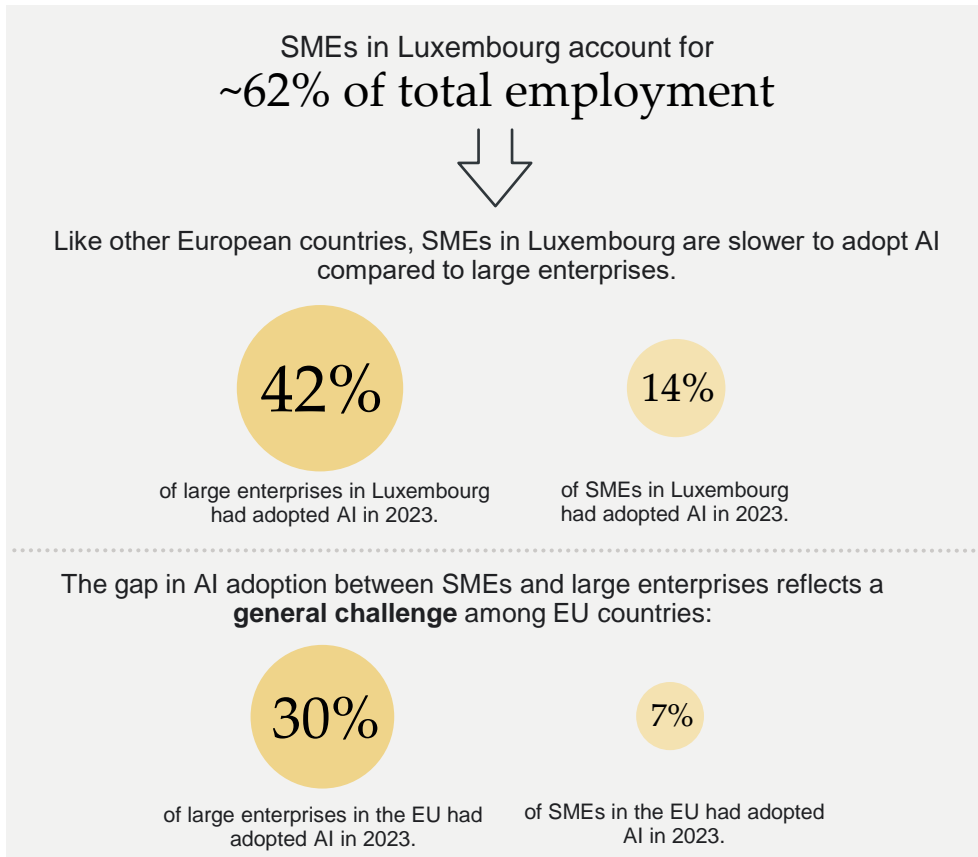
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Adoption of generative AI

%

Scenario with widespread adoption

Scenario with delayed adoption

Scenario with widespread adoption
+9% GDP

annual contribution in around ten years from now if Luxembourg achieves widespread adoption.

Scenario with delayed adoption
+2% GDP

annual contribution if Luxembourg is delayed in achieving widespread adoption of generative AI.

- Generative AI is a new general-purpose technology and will take time to adopt.

- Our estimate of Luxembourg's GDP potential from generative AI is reliant on the widespread adoption and development of the new AI technology within the next ten years.

- A five-year delay in capturing the benefits of generative AI is estimated to reduce the GDP growth potential in ten years from 9% (€6-8 billion) to only 2% (€1-2 billion).

- Luxembourg can enhance the welfare and GDP contribution from generative AI by ensuring that policies are in place to capture the benefits in line with leading countries (see section 6).

Note: GDP figures are expressed in 2022 levels. The figure shows generative AI adoption as a share of economywide companies exposed to AI automation. The estimate is made for a ten-year adoption period to align with the time horizon for widespread adoption by the most advanced countries apart from the US. The "widespread adoption" scenario assumes adoption in line with "other developed markets" in Briggs and Kodnani (2023b).
Source: Implement Economics based on Eurostat, O*Net and Briggs and Kodnani (2023a&b) .

Generative AI models have the potential to boost SME AI adoption to new levels, but regulatory uncertainty and lack of skills can stand in the way

SMEs lag behind larger corporations on AI adoption

SMEs in Luxembourg account for
~62% of total employment

↓

Like other European countries, SMEs in Luxembourg are slower to adopt AI compared to large enterprises.

42%

14%

of large enterprises in Luxembourg had adopted AI in 2023.

of SMEs in Luxembourg had adopted AI in 2023.

The gap in AI adoption between SMEs and large enterprises reflects a **general challenge** among EU countries:

30%

7%

of large enterprises in the EU had adopted AI in 2023.

of SMEs in the EU had adopted AI in 2023.

Generative AI could boost SME AI adoption …

No or low data requirements means that SMEs can readily use generative AI for many tasks without any further work needed.

Ease of use in plain language means that SMEs can use many generative AI models without the need for coding skills.

Free online availability means that SMEs do not need to invest in new computing power or new infrastructure to use generative AI.

… but SME uptake can be slowed down because …

Lack of broader skills required to fully leverage the potential of new generative AI technologies can hamper uptake.

Regulatory uncertainty around generative AI can increase implementation risks and compliance costs, notably for SMEs lacking in-house legal capabilities.

03

Key sectors benefitting from AI

Some sectors are expected to gain more from generative AI, mostly owing to the types of tasks performed.

AI can boost productivity across all sectors – exceeding historical levels

Productivity boost from generative AI
Percentage points productivity growth p.a. at peak

Sector	Value
Construction	0.9
Tourism and other services	1.1
Agriculture and primary sectors	1.2
Transport and storage	1.3
Wholesale and retail trade	1.6
Public administration, education and healthcare	1.6
Manufacturing	1.6
Business services and real estate	1.6
Information and finance	1.8

◄ Economy-wide productivity impact
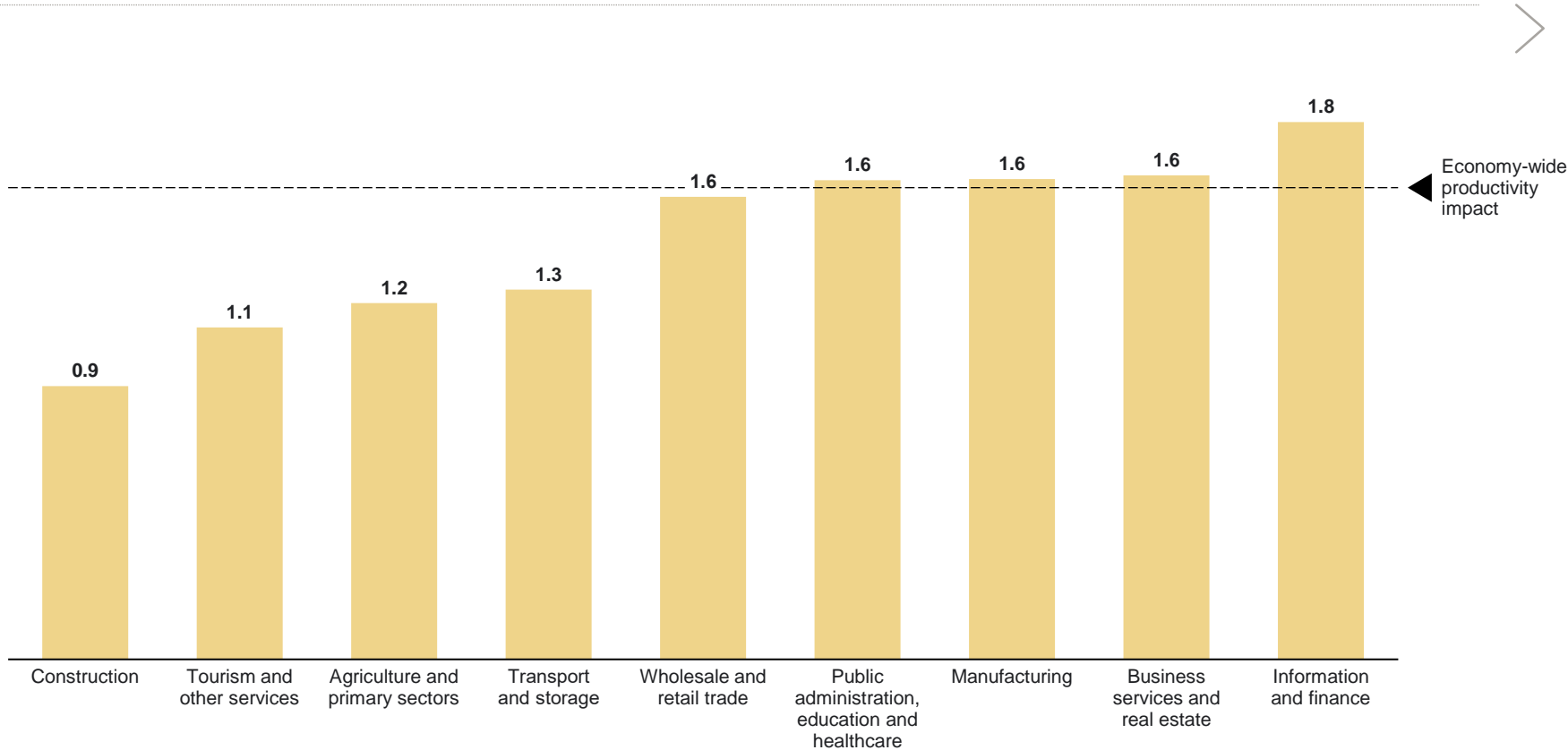
- The complementary role of generative AI prevails in most industries, meaning that most occupations are estimated to use AI to augment and improve human capabilities, providing a large productivity boost.

- In contrast to past automation, such as robots, generative AI has the ability to boost productivity in the service sector.

- In the service sector, productivity increases can be achieved when humans are assisted by generative AI. This can help create content and is estimated to free up time for other valuable tasks. Lawyers can be assisted in reviewing and summarising long documents and in drafting basic documents. Some journalists even use AI to give suggestions for headlines.

- Displacement mainly occurs where administrative and repetitive knowledge-based tasks make up a large part of the work activities.

Note: Sectors are aggregated according to NACE categorisation. "Information and finance" is a combination of information, communication, financial and insurance activities. "Tourism and other services" comprises accommodation, food and other services. Gains in labour productivity are mapped one to one to GDP if total employment (as here) is assumed constant and the capital stock increases to match productivity improvements. The estimates take into account that the growth impact of generative AI may not be fully additive to the current GDP trend. First, AI-related gains may substitute for growth that would otherwise occur in a non-AI baseline. Second, underlying productivity growth has slowed over the past decades. The estimated boost from generative AI may be partially offset by an underlying growth slowdown.
Source: Implement Economics based on Eurostat, Statistiques.lu, OECD, O*Net and Briggs and Kodnani (2023a).

Around 90% of generative AI's economic potential lies in service sectors, while manufacturing and other sectors can also benefit from other types of AI

Gross value added by sector
€ billion

◻ Gross value added in 2022   ◼ Increase from generative AI after a ten-year period

Knowledge-intensive business services
e.g. finance, legal, science and information — **3.5**

Public administration, education and healthcare — **1**

Trade, transport and tourism
e.g. wholesale trade, storage and accommodation — **1**

Manufacturing, construction, energy and water — **0.5**

x-axis: 0 5 10 15 20 25 30 35 40
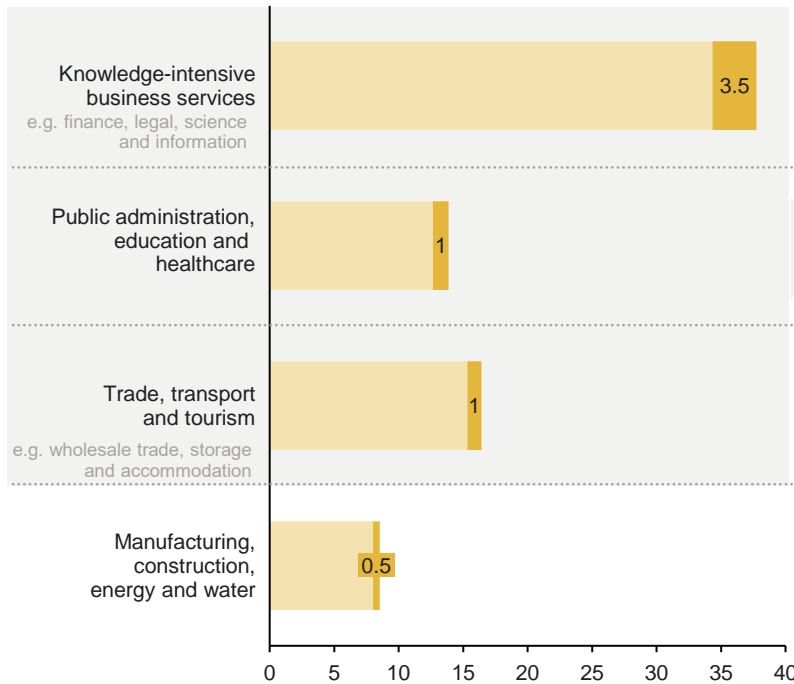
90% of potential

Generative AI has the potential to boost value added in knowledge-intensive business services by around **€3.5 billion**, e.g. by generating content, assisting in research and automating complex data processing. The impact of other types of AI in these sectors is limited to automating repetitive tasks.

Generative AI can benefit the public sector with an estimated **€1 billion**, e.g. through personalised tutoring in education, diagnostic support and patient interactions in healthcare, and automatic document handling and preparatory decision-making in public administration. Other types of AI also have potential in the public sector.

Although the trade, transport and tourism sector has a small percentage impact from generative AI, it still presents a significant economic potential of an estimated **€1 billion** due to its large size. The sector can, for example, benefit from enhanced customer service through responsive chatbots and the processing of legal documents or contracts.

Generative AI has the potential to increase productivity in manufacturing and construction by around **€0.5 billion**, although the percentage impact is assessed to be smaller than in other sectors. Other types of AI are expected to have a significant impact on these sectors, e.g. through supply chain optimisation and automation of manual processes for specific tasks.

Generative AI can increase value generation from the large financial and insurance sector in Luxembourg

Luxembourg GVA 2022
€ billion

€59 billion

Finance and insurance	28%
Other activities	72%
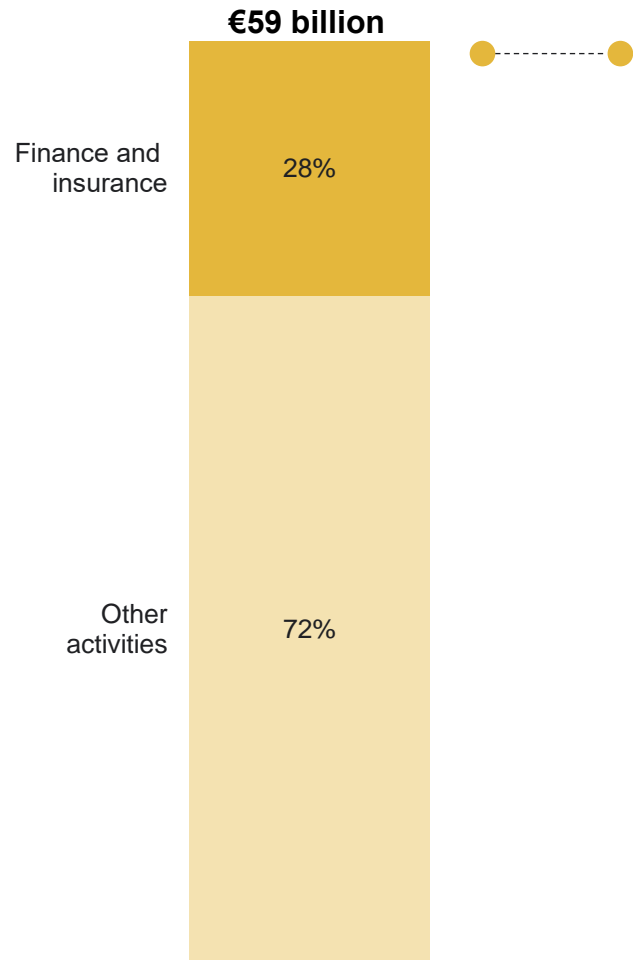
How generative AI can help the financial and insurance sector …

Enhanced risk assessment

- Predictive risk modelling
- Regulatory compliance
- Fraud detection and prevention

Automation and efficiency

- Process automation
- Enhanced decision-making
- Cost reductions

Personalised customer services

- Personalised financial advice
- Customer interactions and support

… and contribute to the economic impact

Reduced financial losses, improved capital efficiency, increased system stability and fewer regulatory penalties.

Higher efficiency and productivity, lower operational costs and improved profit margins.

Higher customer retention rates, reduced service costs and promotion of Luxembourg as a financial innovation hub.

- Finance and insurance is Luxembourg's largest sector, constituting 28% of GVA in 2022.

- With an estimated 1.8% productivity growth boost in the peak year, the sector is expected to benefit greatly from generative AI. This growth is higher than in other sectors due to the prevalence of knowledge-based work in finance and insurance, where generative AI is especially potent.

- Due to the relatively higher productivity growth, the GVA increase in the finance and insurance sector from generative AI is estimated to account for 32% of the total GVA increase in Luxembourg.

- By employing generative AI, the sector can reduce financial risks by enhancing predictive modelling and improving compliance with regulations, which contributes to better financial stability and efficiency.

- Automation driven by generative AI can also boost operational efficiency, leading to lower operational costs and higher productivity through streamlined processes and enhanced decision-making capabilities.

- Furthermore, personalised customer services via generative AI can improve customer satisfaction and retention, reducing service costs and position Luxembourg as a leader in financial innovation and customer care.

04

Job implications of AI

Generative AI will introduce job changes in Luxembourg – the nature and degree of which depend on economic and demographic factors.

Generative AI augments most jobs

Share of jobs exposed to automation by generative AI
% of total employment at workplaces in Luxembourg

515,000 jobs

No automation	22%
AI as a complement	72%
Partial or full displacement	6%

~ 22% of jobs are unlikely to be exposed to automation

An estimated 115,000 jobs in Luxembourg are likely to remain largely unaffected by generative AI. These jobs include manual labour, outdoor tasks, such as construction and cleaning, and human-to-human tasks, such as personal care and food services.

~ 72% of jobs are likely to be augmented by generative AI

Most jobs (roughly 370,000) are expected to be assisted by generative AI by automating a limited share of their tasks and helping to create content (text, code and images), collaborating with workers on complex problems and contributing to product design.

Unlike previous waves of automation that mainly impacted manual workers, generative AI is expected to primarily affect office-based professionals.

~ 6% of jobs are likely to be fully or partially displaced

A smaller number of jobs (around 30,000) are expected to have over half of their work activities exposed to automation by generative AI, e.g. in occupations such as clerical support workers, contact centre salespersons and translators. These workers are likely to see their jobs fundamentally change and may need to be re-employed in new occupations.

Note: Based on Q3 2023 employment data. In accordance with Briggs and Kodnani (2023a), "No automation" are occupations with less than 10% exposure, "AI as a complement" are occupations with 10-49% exposure and "partial or full displacement" are occupations with exposure of or above 50%. Note that percentages and absolute numbers are rounded. Total employment in Luxembourg is 515,000 people, including non-resident workers. In this report, the occupation composition is based on the Labour Force Survey covering resident workers.
Source: Implement Economics based on Eurostat, Statistiques.lu, O*Net and Briggs and Kodnani (2023a).

The AI-powered economy is expected to create new jobs and ensure full re-employment of potentially displaced workers

Share of jobs exposed to automation by generative AI
% of total employment in Luxembourg

- ● Partial or full displacement
- ● AI as a complement
- ○ No automation

6% of jobs in Luxembourg are estimated to be highly exposed to generative AI, leading to some job closures.
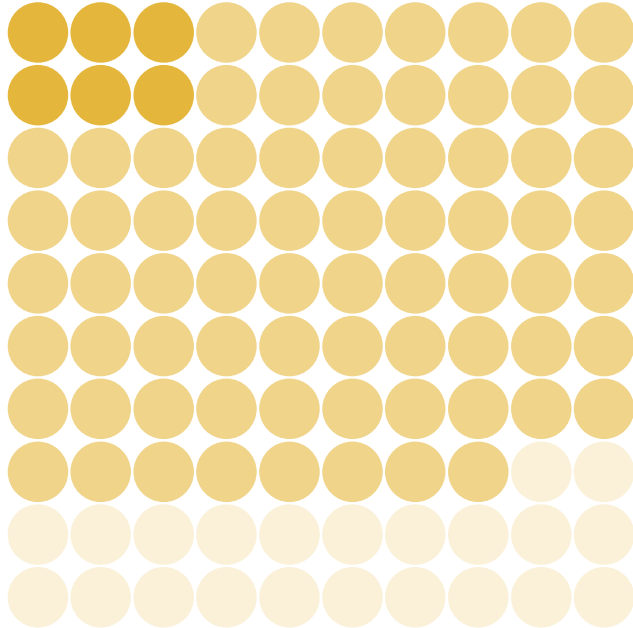
Meanwhile, 72% of jobs are expected to see a boost in productivity. This will create new jobs due to:

I · Increase in general demand for goods and services

With higher GDP growth, the AI-powered economy will demand more labour across a wide range of occupations and skill levels.

II · Creation of new AI-related tasks

Widespread use of AI will also create new jobs such as AI prompt engineers, AI-assisted creative professionals and AI application specialists – and create jobs we cannot preconceive.

III · Demand within occupation

Generative AI will also make highly exposed occupations, such as translators, more efficient, and hence cheaper, which in turn can increase the demand for those occupations.

Even with accelerated and broad adoption of generative AI over a ten-year period, only around 2,000-3,000 people in highly exposed jobs are estimated to need re-employment per year, which is low compared to the 30,000 expected future job openings each year towards 2035 according to CEDEFOP (see page 23).

- The job development in Luxembourg over the next decades will depend on a range of factors.
- The isolated impact of generative AI depends on the speed of adoption and size of the productivity boost relative to the size of the displacement effect for the jobs that are highly exposed to generative AI.
- This report assumes full re-employment of displaced workers over a ten-year period. This means no net change in total employment or unemployment.
- This assumption builds on the large size of the productivity boost compared to the relatively small share of displaced jobs. This suggests that the demand for new jobs will be sufficiently strong to create jobs for those exposed.
- Furthermore, economic theory suggests that long-term employment is determined by the labour supply and skill mix of the workforce.
- The short-term job impacts will depend, among other things, on the flexibility of the labour market as well as re-training and skilling opportunities for workers.

Note: The assumption that labour supply predetermines employment is widely applied by economists. See, for example, *Principles Of Economics* by N. Gregory Mankiw (2020). Total employment in Luxembourg is 515,000 people, including non-resident workers. In this report, the occupation composition is based on the Labour Force Survey covering resident workers.
Source: Implement Economics based on based on Eurostat, Statistiques.lu, O*Net and Briggs and Kodnani (2023a).

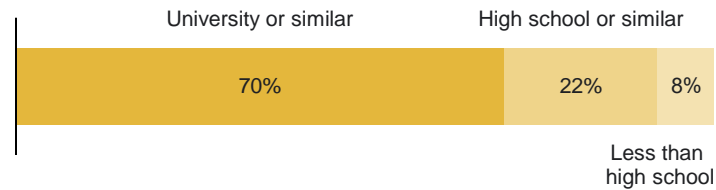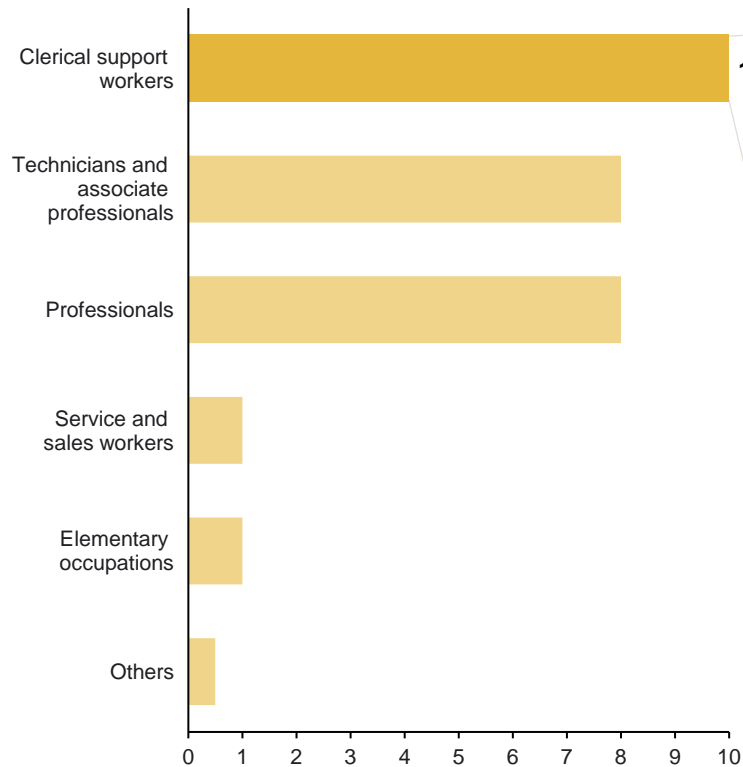# 370,000 jobs are expected to be complemented by AI – mainly highly educated professionals

Jobs complemented by generative AI
Thousand jobs

Legend: ■ University or similar ■ High school or similar ■ Less than high school
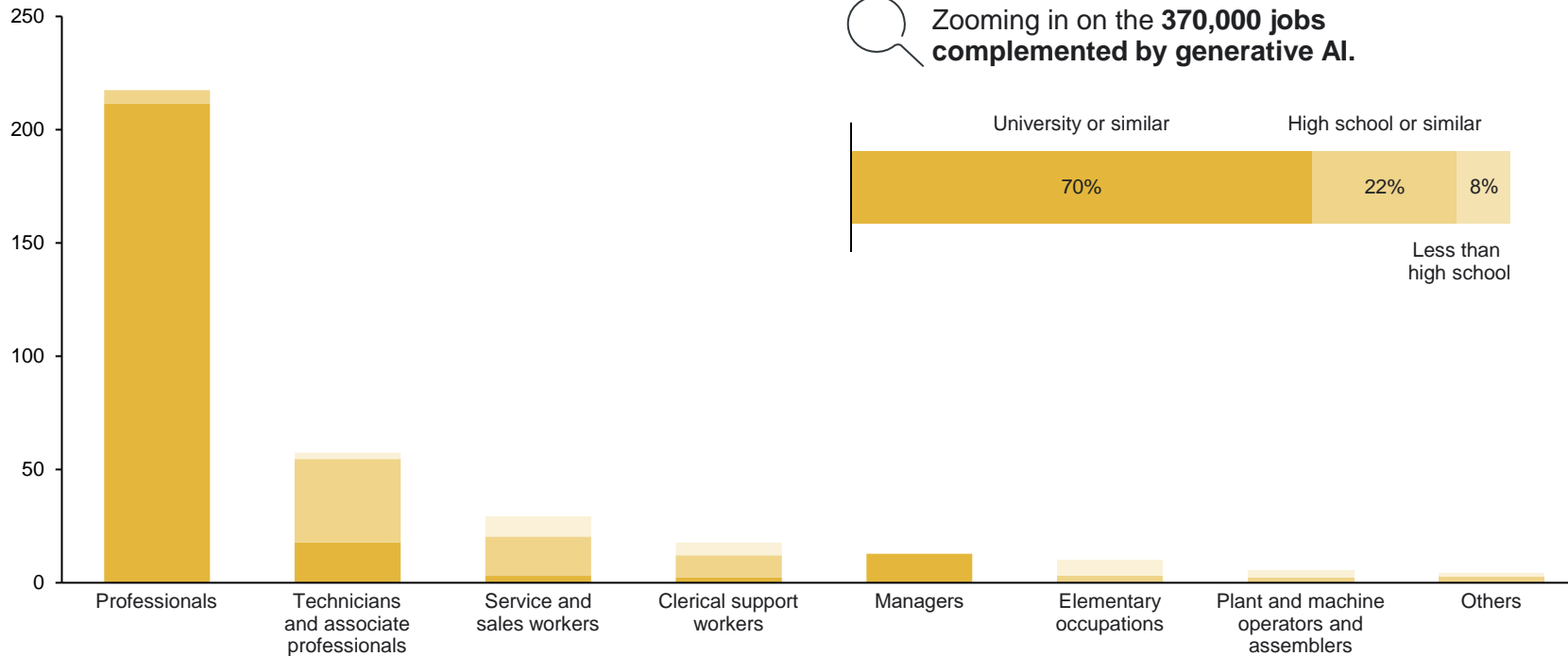
Zooming in on the **370,000 jobs complemented by generative AI.**

University or similar — 70%
High school or similar — 22%
Less than high school — 8%

Chart categories (x-axis): Professionals | Technicians and associate professionals | Service and sales workers | Clerical support workers | Managers | Elementary occupations | Plant and machine operators and assemblers | Others

Examples of jobs include:							
Research, analysis and advising services (including legal)	Engineering technicians, robot controllers and air traffic safety technicians	Caterers, housekeepers and travel agents	Secretaries, record keepers and information suppliers	Executives and supply and general managers	Cleaners, washers and delivery	Train drivers and machinery operators	Police services and farmers

- Generative AI is estimated to augment the capabilities of around 370,000 jobs in Luxembourg at full adoption and around half of these over a ten-year period.

- Of the complemented workers, 70% are estimated to hold higher educational attainment, such as lawyers, scientists and engineers.

- Generative AI can perform complex cognitive tasks and complement human abilities, creating opportunities for individuals to work with generative AI to create new content and free up time for other tasks.

- Unlike previous waves of automation, generative AI is less relevant in jobs carried out by those with lower levels of educational attainment.

Note: Based on Q3 2023 employment data. Total employment in Luxembourg is 515,000 people, including non-resident workers. In this report, the occupation composition is based on the Labour Force Survey covering resident workers.
Source: Implement Economics based on Eurostat, Statistiques.lu, O*Net and Briggs and Kodnani (2023a).

6% of jobs in Luxembourg are highly exposed to generative AI, but the AI-powered economy will help create new jobs

Jobs highly exposed to generative AI
Thousand jobs

Chart — horizontal bars:
- Clerical support workers: 10
- Technicians and associate professionals: ~8
- Professionals: ~8
- Service and sales workers: ~1
- Elementary occupations: ~1
- Others: ~0.5

X-axis: 0 1 2 3 4 5 6 7 8 9 10

Highly exposed jobs in total: 30,000 jobs

Example: Luxembourger clerical support workers and job transition

Of the 10,000 highly exposed clerical support workers, only around half are assumed to be affected by generative AI over ten years, and all of these are assumed to be employed either outside or within the occupation.

Most are expected to be re-employed in other occupations due to:

I — **Increase in general demand for goods and services** due to increased income in the AI-powered economy, leading to job opportunities in other sectors.

II — **New types of AI-related tasks created** arising from the introduction of generative AI such as AI prompt engineers, AI-assisted creative professionals and AI application specialists.

A smaller share is expected to be employed *within* occupation because:

III — **Not all highly exposed workers will be displaced.** Some will continue to hold employment with new tasks replacing the exposed tasks.

Increased demand within occupation due to the increase in productivity and lower costs.

The proportion of employment within occupations and in new occupations is uncertain.

Bar: Within occupation ←→ Re-employed — **10,000**

- Around 30,000 jobs in Luxembourg are estimated to be highly exposed to generative AI at full adoption, and around half of these are expected to be affected over a ten-year period.

- This report assumes full re-employment of displaced workers. This means no net change in total employment or unemployment.

- The Luxembourgish economy is thus assumed to be able to sustain at least the current level of employment in the coming 10-15 years as also predicted by EU forecasts from CEDEFOP.

- Clerical support workers, technicians and service and sales workers are highly exposed to generative AI and up to a third of these jobs are expected to see significant change.

- The transition is likely to be gradual, allowing workers time to adapt to new tasks and skills.

- Through three channels, the AI-powered economy will gradually lead to new jobs and support employment within the occupation or re-employment in other sectors.

- Historically, worker displacement from automation has been offset by the creation of new jobs, and the emergence of new occupations following technological innovations accounts for the vast majority of long-run employment growth.
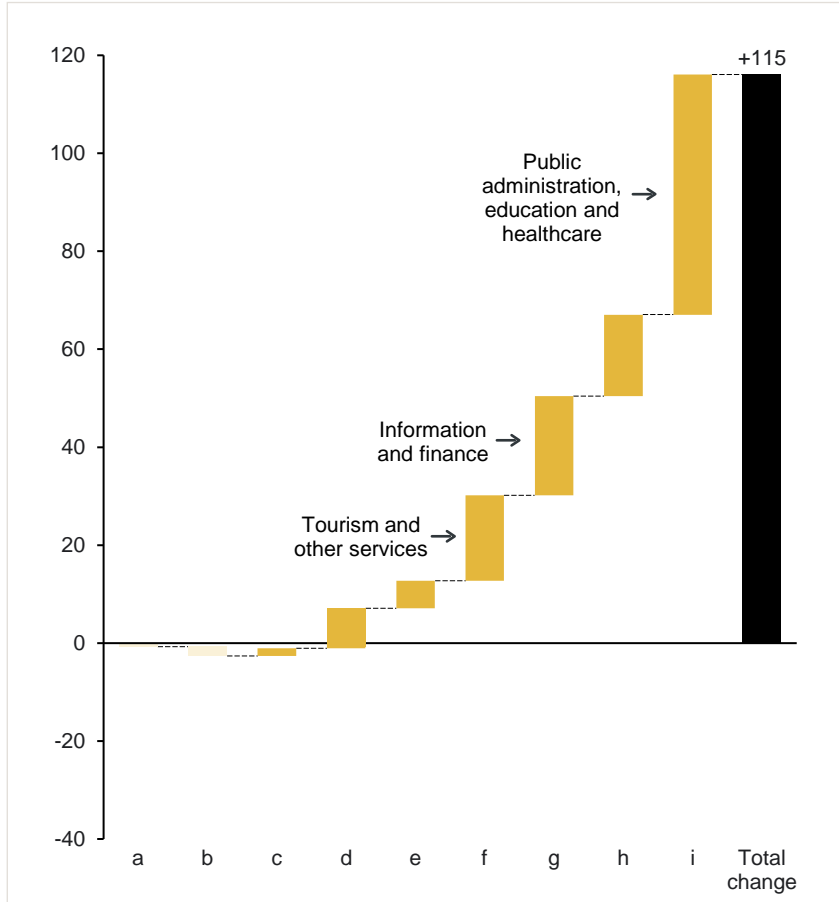
Note: Based on Q3 2023 employment data. High exposure to AI does not automatically imply full displacement of all workers in that occupation. In the GDP estimates, we make a conservative assumption, assuming low automation to avoid overestimating GDP impacts. In the job exposure and potential displacement assessment, we show the full size of the potential displacement to avoid underestimating the job implications. The size of each re-employment channel is uncertain and depends on how the technology is adopted and the interplay between increased efficiency and how unmet demand translates into increased or decreased employment in various occupations. Total employment in Luxembourg is 515,000 people, including non-resident workers. In this report, the occupation composition is based on the Labour Force Survey covering resident workers.
Source: Implement Economics based on Eurostat, Statistiques.lu, O*Net and Briggs and Kodnani (2023a).

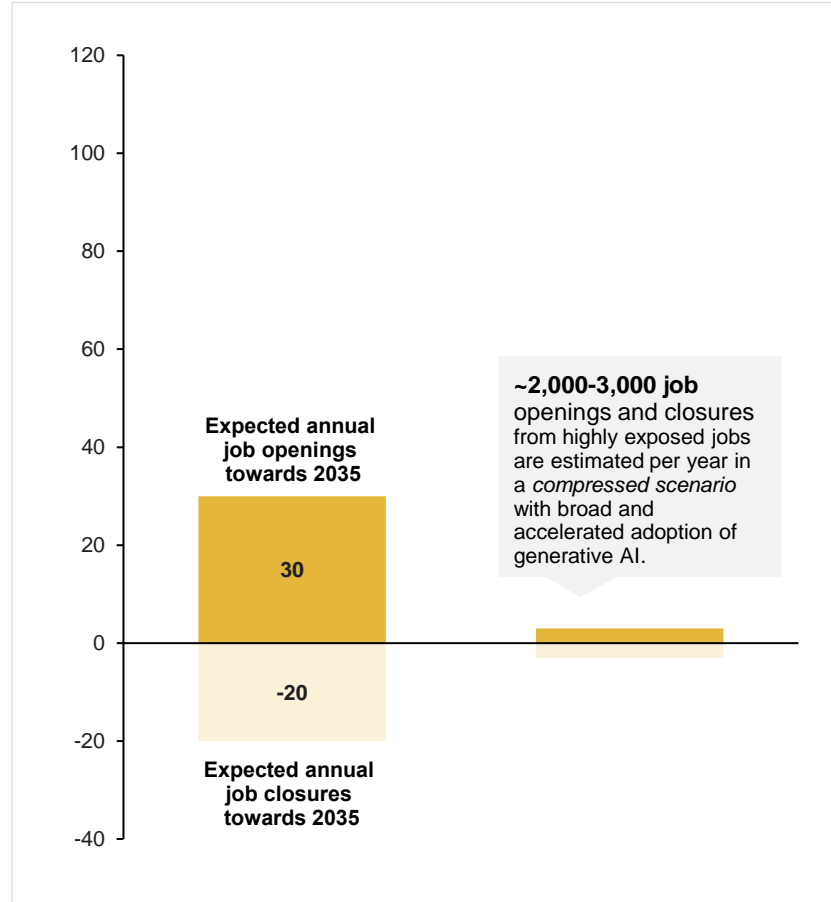# Job changes from generative AI are small compared to expected future averages

Change in employment across sectors in Luxembourg, 2013-2022
Thousand jobs

+115

Public administration, education and healthcare

Information and finance

Tourism and other services

a b c d e f g h i Total change

Estimated annual re-employment in Luxembourg from generative AI
Thousand jobs

Expected annual job openings towards 2035

30

-20

Expected annual job closures towards 2035

~2,000-3,000 job openings and closures from highly exposed jobs are estimated per year in a *compressed scenario* with broad and accelerated adoption of generative AI.

- Luxembourg's economy has added around 115,000 jobs over the last ten years. Only the manufacturing and construction sectors have contracted, while most other sectors have added significant amounts of new jobs, e.g. tourism, information and finance, and the public sector.

- In addition, numerous new jobs are created and closed every year in each sector to adapt to changing needs and demands.

- According to CEDEFOP, Luxembourg's economy is expected to see around 30,000 job openings and 20,000 job closures every year until 2035.

- We estimate that the jobs that are highly exposed to generative AI can lead to 2,000-3,000 annual job openings and closures over the coming ten years. This is around 7-10% of the expected future annual number of job openings in Luxembourg.

- The labour market effects stemming from generative AI's impact on highly exposed jobs are thus small compared to expected future levels of job changes.

- To avoid underestimating the possible job impacts of generative AI, these estimates are in a compressed scenario with broader and more accelerated adoption of generative AI than in our estimates of the GDP impacts.

Note: a. Agriculture and primary sectors; b. Manufacturing and construction; c. Utilities, raw materials and waste; d. Wholesale and retail trade; e. Transport and storage; f. Tourism and other services; g. Information and finance; h. Business services and real estate; i. Public administration, education and healthcare. Our GDP estimate makes conservative assumptions around the scope of tasks for generative AI and the speed of adoption as in the base scenario in Briggs-Kodnani (2023a). The *compressed scenario* used to gauge the potential job market implications assumes faster adoption (full adoption over ten years) and/or more broad application of generative AI (as in the Briggs-Kodnani scenario with "more labour displacement").
Total employment in Luxembourg is 515,000 people, including non-resident workers. In this report, the occupation composition is based on the Labour Force Survey covering resident workers.
Source: Implement Economics based on Eurostat, Statistiques.lu and CEDEFOP.

A higher share of female workers are estimated to be affected by generative AI – both regarding potentially positive and negative impacts

Share of female jobs exposed to automation by generative AI
% of total employment among female workers

Total ~ 215,000 female workers

No automation	**19%**
AI as a complement	**75%**
Partial or full displacement	**6%**
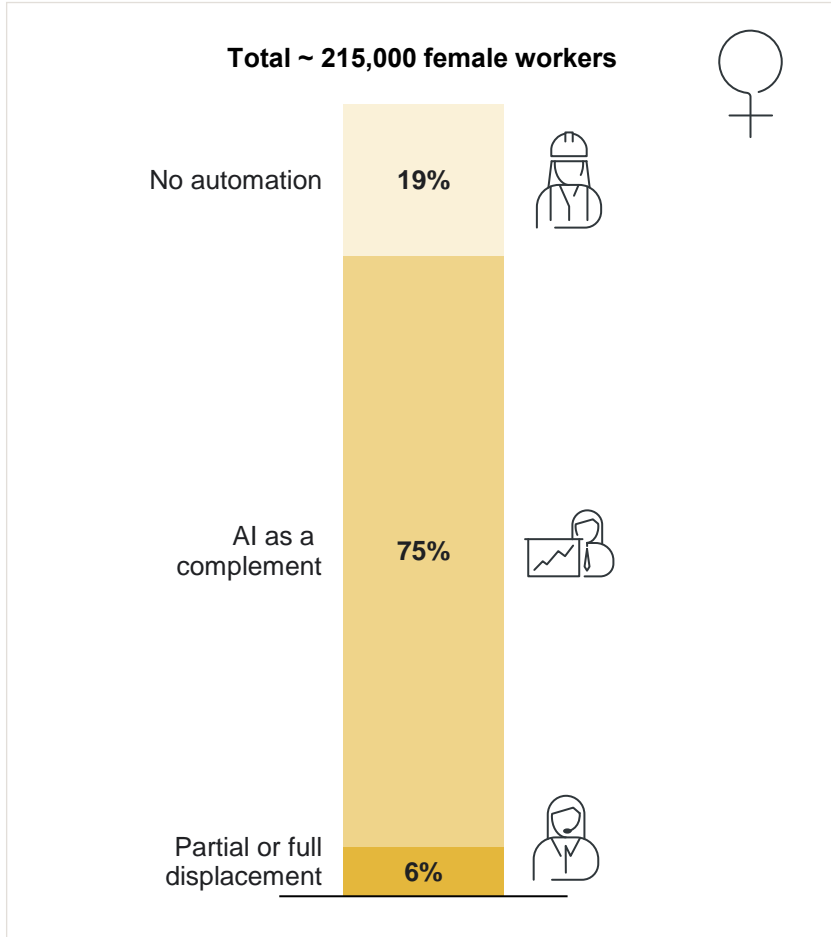
Share of male jobs exposed to automation by generative AI
% of total employment among male workers

Total ~ 300,000 male workers

No automation	**24%**
AI as a complement	**71%**
Partial or full displacement	**5%**
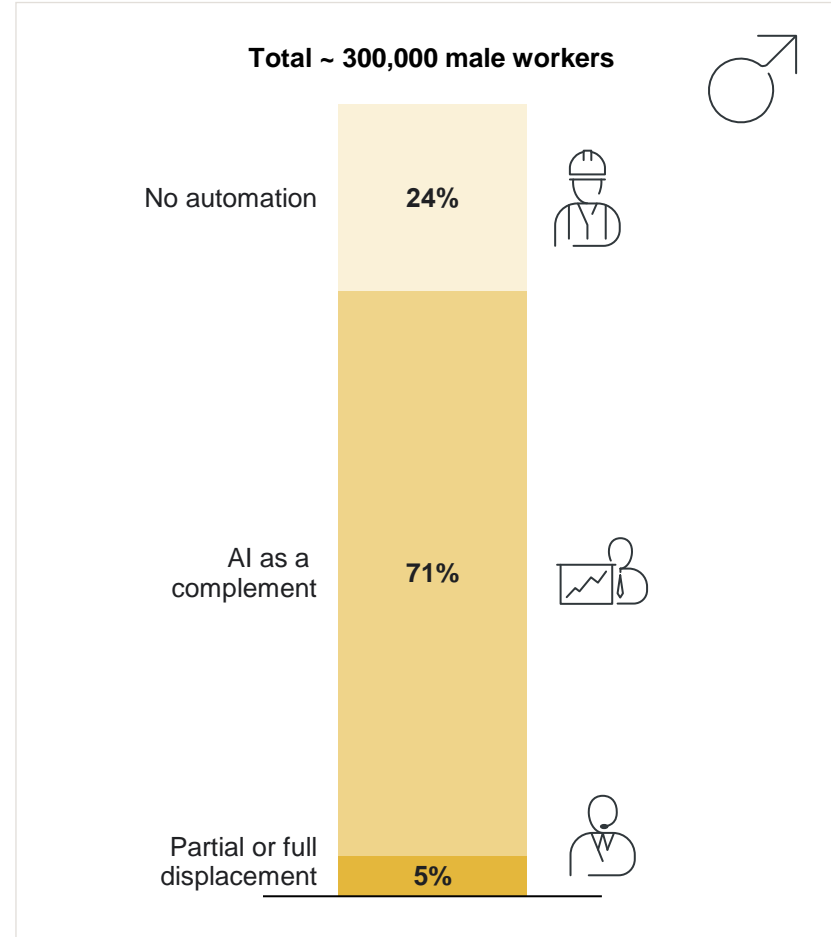
No automation

- 19% of female workers and 24% of male workers in Luxembourg are in jobs with limited exposure to generative AI. These are, for example, manual, outdoor and human-to-human jobs.

Complemented jobs

- 75% of female workers are expected to see generative AI complement their current job, whereas the share is 71% for male workers. Female workers are, to a higher degree than men, employed in jobs such as teachers and lawyers, where generative AI is expected to augment human capabilities and make workers more productive.

Potentially displaced jobs

- 6% of female workers and 5% of male workers in Luxembourg are currently in jobs such as clerical work, call centre workers and technicians that are likely to be highly exposed to automation by generative AI and hence more at risk of seeing their current job being fully or partially displaced by the new technology.

Note: Based on Q3 2023 employment data. In accordance with Briggs and Kodnani (2023a), "No automation" are occupations with less than 10% exposure, "AI as a complement" are occupations with 10-49% exposure, "Partial or full displacement" are occupations with exposure of or above 50%. Note that percentages and absolute numbers are rounded. The share of male-to-female workers reflects domestic payroll employment by gender.
Source: Implement Economics based on Eurostat, Statistiques.lu, O*Net and Briggs and Kodnani (2023a).

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75% of workers in Luxembourg see productivity-enhancing effects of generative AI, and 43% of workers in European countries expect AI to positively impact their job

Workers in Luxembourg think that generative AI makes them more productive

Generative AI will help improve my productivity at work
Workers who agree, %

Avg. 75%

NO 84% | DK 81% | BE 76% | FI 76% | LU 75% | NL 70% | SE 66%
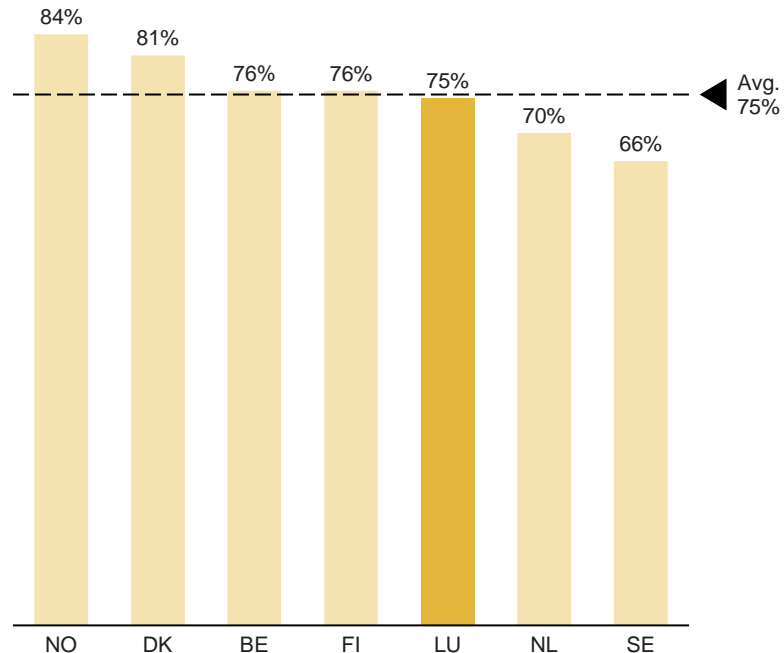
Workers in European countries think that AI will positively impact their job

How will AI impact your job over the next five years?

	Negatively	Positively
All workers	18%	43%
Higher-educated workers	16%	49%
Workers who have used an AI application in the last 12 months	16%	57%
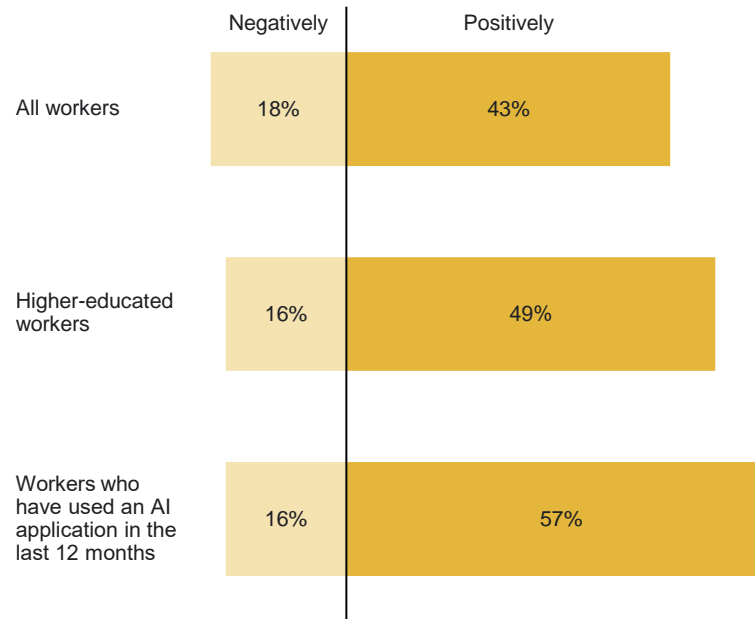
- Polling conducted by Public First shows that 75% of workers in Luxembourg think that generative AI will help them be more productive, which is in line with the average of other European countries. This could, for example, be through optimising workflows, automating certain tasks and enhancing capabilities.

- A recent Ipsos survey on attitudes towards AI reveals that 43% of workers in the surveyed European countries expect AI to have an overall positive impact on their job while only 18% expect a negative impact.

- The positive expectations are more pronounced for higher-educated workers with 49% expecting a positive job impact.

- Workers who have used an AI application in the past 12 months have the most positive expectations, with 57% expecting AI to have a positive impact on their job in the future.

Note: Public First survey conducted in summer 2023. Nationally representative consumer and business polling. Respondents of the survey include Sweden (SE), Denmark (DK), the Netherlands (NL), Belgium (BE), Luxembourg (LU), Finland (FI) and Norway (NO). Averages across countries are computed as arithmetic means. The surveyed European countries in the Ipsos survey are Belgium, France, the Netherlands, Spain and Sweden.
Source: Implement Economics based on Public First country surveys and Ipsos survey.

Workers need a broad set of skills for effective use of generative AI

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Multiple skills are needed to leverage generative AI …

Skill needs in the age of AI (incl. both generative and traditional) OECD

Skills …	*Type of skills*	*Examples*
… for developing and maintaining AI systems.	Specialised AI skills	Machine learning capabilities and knowledge
	Data science skills	Data analysis and visualisation, cloud computing and programming
	Other cognitive skills	Create problem-solving
	Transversal skills	Social skills and management skills
… for adopting, using and interacting with AI applications.	Elementary AI knowledge	Principles of machine learning
	Digital skills	Ability to use computer/smartphone
	Other cognitive skills	Analytical skills, critical thinking and problem-solving
	Transversal skills	Creativity, communication, teamwork and multitasking

… and European workers express a need for reskilling

What will you do in the next five years as a result of AI?
% of respondents who are employed and think that AI will slightly or completely transform the way they do their job.

I will have to reskill or take some type of course

France	37%
Spain	35%
Sweden	33%
Belgium	30%
Netherlands	26%
Germany	18%
Poland	14%

Avg. 28%
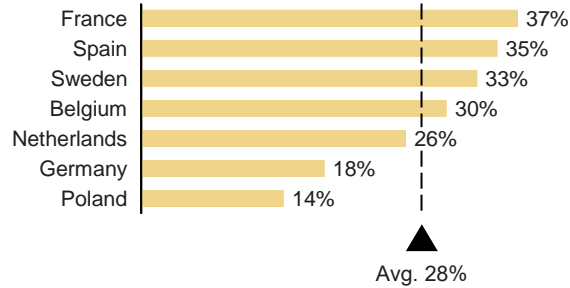
I will have to learn how to use AI

Spain	50%
Sweden	43%
Poland	36%
Netherlands	36%
Belgium	36%
Germany	33%
France	29%

Avg. 38%
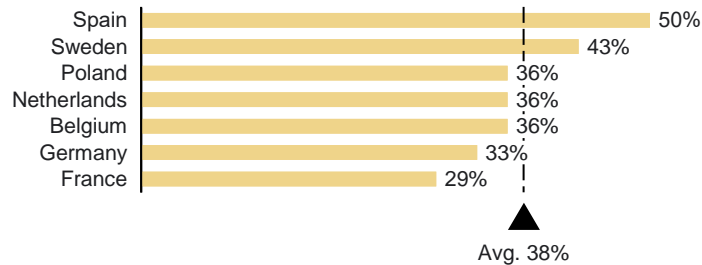
- Generative AI adoption and usage requires limited digital skills relative to earlier advancements in information and communication technology (ICT) due to its ease of use via normal language prompts.

- However, fully leveraging generative AI requires skills beyond basic digital skills, i.e. creative, managerial and analytical skills.

- Of the polled European workers indicating that AI will completely or slightly change their job, an average of 28% expect to have to reskill or take some type of course in the next five years as a result of AI.

- OECD studies suggest that companies that provide ICT training for their employees on average have 3-5% higher growth in their annual labour productivity.

- The literature highlights that companies that combine technology/ICT adoption with employee training have higher implementation and financial success.

Generative AI can help close the skills gap for those with the lowest skill levels

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Grades with and without generative AI

Estimated mean grade on 2nd task

Mean grade on 2nd task (y-axis: 0.0 to 6.0)

With generative AI
Without generative AI

+52%
+2%

Lowest performing cohort → Highest performing cohort

Cohort based on grade on 1st task
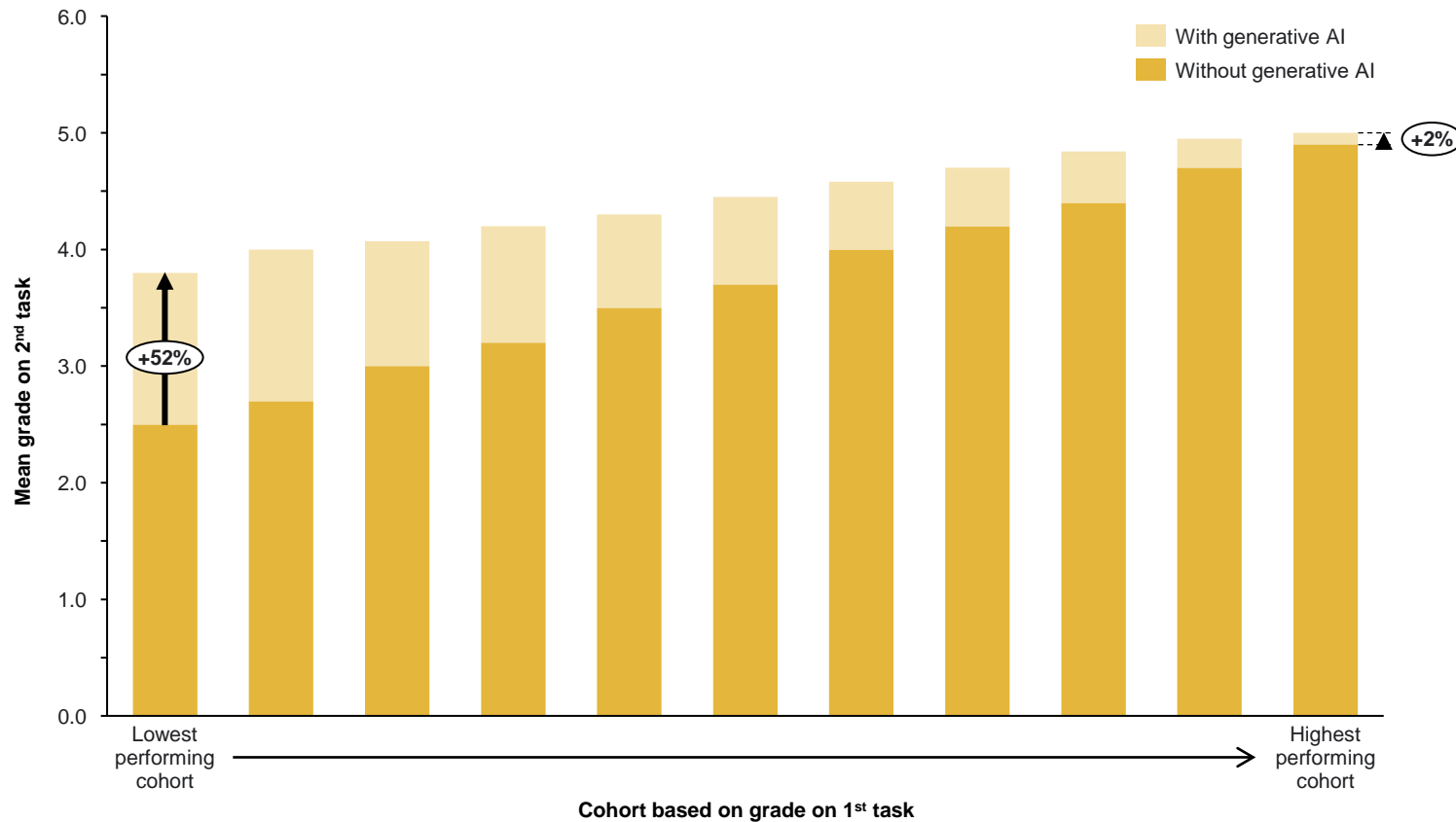
- AI requires a broad skill set to reap the benefits. However, AI as a tool can itself augment the performance of human skills.

- Furthermore, generative AI can help close the skills gap by increasing the performance of those with the lowest skill levels.

- An experimental study by Noy and Zhang (2023) tested experienced professionals' writing skills with and without access to generative AI.

- Participants were given tasks such as writing press releases, short reports and emails, which were graded by evaluators on a 1-7-point scale.

- The results showed that, on average, all professionals were able to boost their grades on their written tasks with the use of generative AI – in this case, a large language model.

- The AI augmentation effect was largest among those with the lowest performance on the first task.

- The lowest-performing group increased their average grade by more than 50% when allowed to interact with a large language model, whereas the best-performing group increased performance by 2%.

- This study is an early indication that generative AI has the potential to boost skills for everyone *and* reduce skill inequalities in the labour market.

Note: The graph shows mean estimates for cohorts.
Source: Implement Economics based on Noy and Zhang (2023), Brynjolfsson et al. (2023) and Dell'Acqua et al. (2023).

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05

AI's impact on societal challenges

AI can help with some of Europe's most pressing societal challenges.

AI can play a key role in addressing climate change

67% of Luxembourgers say that they support AI tools being used to help them make more environmentally sustainable choices in their lives.

64% of Luxembourgers support AI tools being used to reduce carbon emissions by managing energy use.

Public First poll

Luxembourg's gross greenhouse gas emissions, 2021
MtCO$_2$e

8%	18%	19%	52%

Gross GHG emissions
9.4
MtCO$_2$e

- Artificial intelligence and other digital solutions are expected to play a key enabling role in reaching Luxembourg's climate goals of net carbon neutrality by 2050.

- Large gains arise from facilitating the electrification of vehicles, where AI and other digital solutions are crucial to optimising the charging of EVs, providing a cleaner and cheaper solution for consumers.

- New building management systems using AI and machine learning can also improve energy efficiency of office buildings and shops. Digital solutions can also help enable the switch to heat pumps and/or intelligent district heating.

- In manufacturing, AI and other digital solutions can help optimise energy efficiencies as well as reduce overproduction by more accurately forecasting demand.

- AI and other digital technologies can play a significant role in decarbonising the energy sector by supporting the transition to flexible energy utilisation and smart grids.

Decarbonisation initiatives enabled by AI and other digital technologies
(non-exhaustive)

Buildings
- Smart buildings
- Transition to heat pumps
- Improved energy efficiency
- Sustainable building materials

Manufacturing
- Smart factory with AI systems
- Efficiency improvements
- Electrification of lighter processes

Domestic transport
- Electric cars, vans, buses and small trucks
- Efficient and eco-friendly driving
- Reduced travel by use of digital tools (working from home and video conferences)

AI can help optimise delivery of healthcare services in Luxembourg and enhance the treatment and prevention of diseases

Luxembourg boasts low levels of medical unmet needs and effective public health interventions. Nearly 7% of Luxembourg's total health spending, among the highest in the EU, was spent on preventative care.

However, a growing elderly population, rising healthcare costs and workforce shortages pose challenges for the resilience of the country's healthcare system. This can, for example, be seen in waiting times, which are an issue across most services, from specialist appointments to emergency care.

More hands are needed

- Luxembourg has fewer doctors per 1,000 people than the EU average. Moreover, the country is dependent on foreign-trained doctors from neighbouring countries due to its small size and the absence of medical training in the country until 2021.
- A scarcity of healthcare professionals leads to lower quality services, incl. longer waiting times, and overworked professionals.

Better treatment and care is required

- An ageing population requires more healthcare services and specialised care.
- Rising living standards drive up societal expectations for healthcare services.
- Chronic diseases are becoming more challenging and rare diseases more common.

Hospitals in Luxembourg are already testing various highly specialised AI tools.

Radiological image analysis solution for diagnostic support

- Since 2019, Luxembourg hospital group Hôpitaux Robert Schumain (HRS) has been using a radiological image analysis solution based on the Biomind AI system.
- The solution provides support to doctors in the analysis and diagnosis of various neurological disorders with the aim of improving accuracy and speed of neurological assessments.
- Similarly, it can help alleviate the pressure associated with the shortage of imaging specialists and radiologists.

Luxembourg's National AI Strategy acknowledges AI's immense potential in further advancing preventive healthcare, disease diagnosis and treatment while increasing the efficiency of the healthcare system.

Given the country's ageing population, the strategy underscores the imperative for health institutions and service providers to leverage AI's capabilities effectively.

AI can help free up and optimise critical resources by …

- Automating tasks in healthcare administration, e.g. appointment scheduling.
- Recording and summarising appointment notes, referral information and care plans.
- Faster and more accurate screening and decisions by physicians.
- Enabling physicians to undertake remote consultations.

AI can help improve how we treat patients by …

- Analysing and enhancing medical images, enabling faster detection of diseases and injuries.
- Improving detection of complex and rare diseases with training data sets and smarter diagnostic tools.
- Predicting individual treatment responses by analysing different patient data.
- Enabling the development of targeted therapies.
- Tracking health issues and accidents through wearable devices and sensors.

Public First poll **50%** of Luxembourgers support AI tools being used to track their medical data.

06

AI readiness in Luxembourg

Luxembourg's capacity to leverage the potential of AI can be evaluated based on several factors and compared to European and global frontrunners.

In assessing Luxembourg's AI readiness, we compare with other small digital frontrunner countries in Northern Europe

- In assessing Luxembourg's AI readiness, we can compare Luxembourg to a comparable group of small, digitally advanced and open European economies.

- Big economies, such as the United States, have an advantage when it comes to scale, i.e. absolute AI capacity, including the amount of commercial activity, availability of funding and volume of R&D.

- Common indicators, such as the Tortoise Global AI Index, compound both **scale** and **intensity** (AI capacity relative to population or GDP).

- As a small country, Luxembourg cannot compete on scale on, for example, the absolute amount of AI-related R&D investment. Luxembourg will be dependent on EU-wide initiatives.

- Therefore, Luxembourg should work for initiatives at EU/Benelux level.

The digital frontrunners of Northern Europe

Finland
#1 in DESI in 2022

Denmark
#2 in DESI in 2022

The Netherlands
#3 in DESI in 2022

Sweden
#4 in DESI in 2022

Norway
#5* in DESI in 2022

Ireland
#5 in DESI in 2022

Luxembourg
#8 in DESI in 2022

Estonia
#9 in DESI in 2022

Belgium
#16 in DESI in 2022

Note: Ranking within the EU is shown. *) When we include Norway, it ranks #5 in DESI in the region.
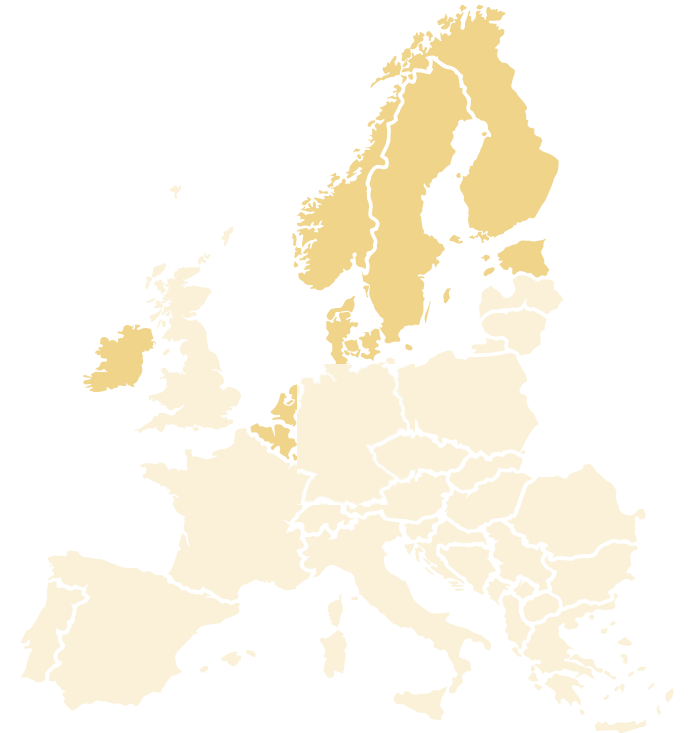
AI adoption in Luxembourgish enterprises is well above the EU average but still far from the EU 2030 target of 75% adoption

Adoption of AI in 2023
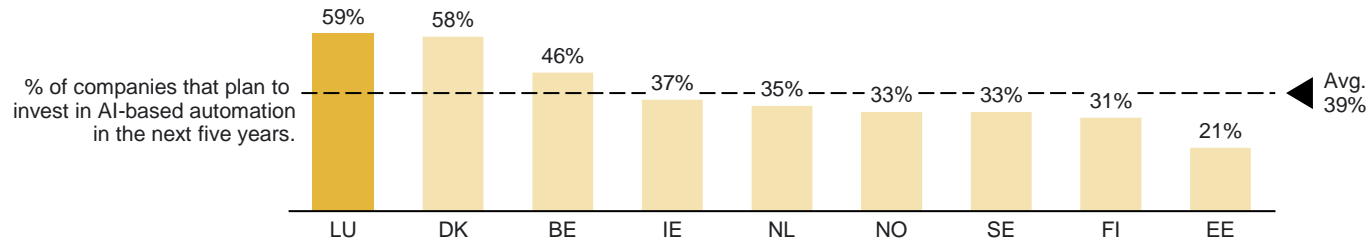% of enterprises using at least one type of AI technology

75% Compass target for 2030

Forecast 2030 at current trajectory

	DK	FI	LU	BE	NL	SE	NO	IE	EU	EE
	15%	15%	14%	14%	13%	10%	9%	8%	8%	5%
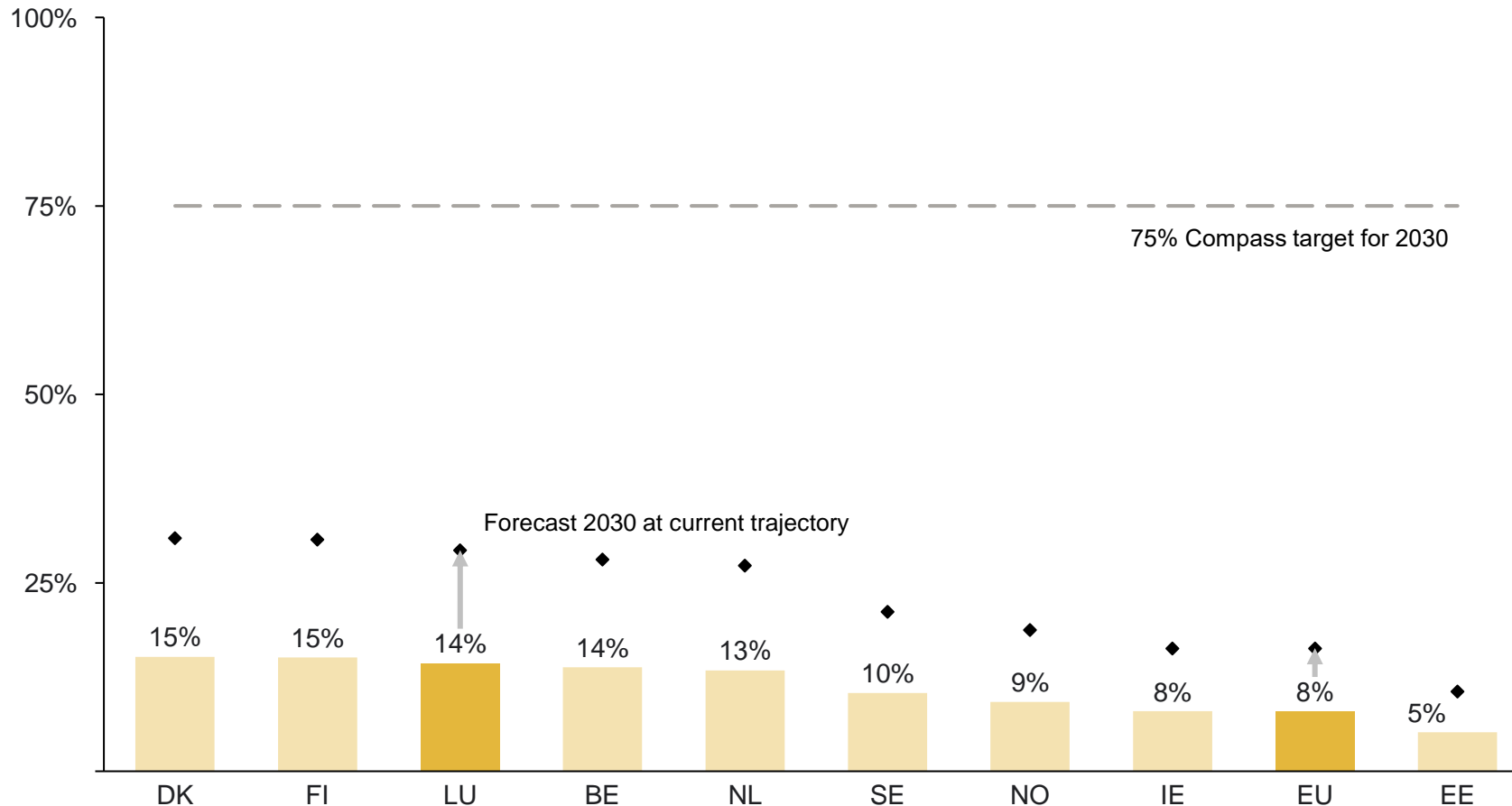
- Luxembourg ranks third among Northern European frontrunners on AI adoption by enterprises. 9% of Luxembourgish companies had adopted at least one type of AI technology in 2023.

- In its most recent assessment, the European Commission concludes that the EU is set to fall significantly short of its target on AI adoption for 2030.

- If we assume the same pace of adoption as the EU average, there is a risk that Luxembourg will fall short of the 2030 target.

- Firm-level adoption data underestimates actual use in business settings (see page 7) as many instances of individual-level AI use are not captured.

Note: Current adoption is from 2023 and includes enterprises with ten or more employees, excluding financial services. Forecast for 2030 is based on European Commission-forecasted AI adoption.
Source: Implement Economics based on Eurostat and the European Commission.

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New survey data points to accelerated adoption but not enough to reach full potential

Survey responses from companies on their five-year outlook on generative AI

% weighted average of enterprises, 2023

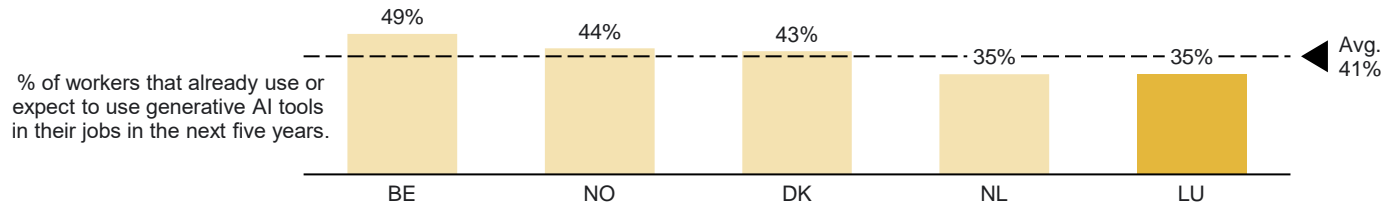**Planned firm-level adoption of AI automation**

% of companies that plan to invest in AI-based automation in the next five years.

59%	58%	46%	37%	35%	33%	33%	31%	21%
LU	DK	BE	IE	NL	NO	SE	FI	EE

Avg. 39%

Expected productivity boost from generative AI

% of companies that think that generative AI will significantly improve the productivity of their business in the next five years.

58%	51%	37%	34%	29%	28%	24%	22%	18%
LU	DK	BE	IE	SE	NL	FI	NO	EE

Avg. 33%
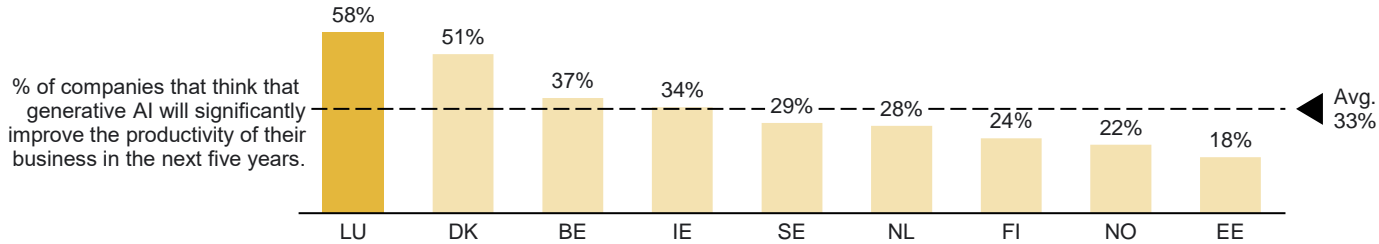
Survey responses from workers on their five-year outlook on generative AI

% weighted average of employees, 2023

Expected use of generative AI at work

% of workers that already use or expect to use generative AI tools in their jobs in the next five years.

49%	44%	43%	35%	35%
BE	NO	DK	NL	LU

Avg. 41%

- Recent polling data from Public First indicates a particularly optimistic outlook on generative AI in Luxembourg compared to many of its Northern European counterparts.

- According to the polling, 59% of companies in Luxembourg claim that they plan to invest in AI-based automation in the next five years, significantly surpassing the average of other surveyed Northern European frontrunners.

- 58% of companies in Luxembourg anticipate significant productivity impacts from generative AI on their business in the next five years. This is again considerably higher than the Northern European frontrunner average.

- 35% of all workers surveyed in Luxembourg already use or expect to use generative AI tools in their jobs within the next five years, which is slightly below the Northern European frontrunner average of 41%.

- While this generally suggests a fast pace of adoption, AI adoption is still in an early phase, and more complementary innovations, investments and commercial ventures in AI are needed to capture the full economic potential.

Note: Public First survey conducted in summer 2023 and Q1 2024 for Estonia and Ireland. Nationally representative consumer and business polling. Respondents of the survey include Sweden (SE), Denmark (DK), the Netherlands (NL), Belgium (BE), Luxembourg (LU), Finland (FI), Norway (NO), Estonia (EE) and Ireland (IE). Worker responses are not available for Finland, Sweden, Estonia and Ireland. Averages across countries are computed as arithmetic means.
Source: Implement Economics based on Public First country surveys.

Drivers of AI adoption suggest that Luxembourg performs well on basic adoption drivers, such as infrastructure and operating environment, but lags behind on innovation drivers

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Luxembourg's AI capacity according to the Tortoise Global AI Index
Global AI Index, score out of 100 (global leader)

Legend: ■ Luxembourg ■ N. European frontrunners ■ Global maximum   100 ▼

	Global leader	Luxembourg ranking	
		N. European frontrunners	Global
AI adoption drivers			
Operating Environment — 90	🇩🇰	4	14
Infrastructure — 75	🇺🇸	1	6
Government Strategy — 67	🟢	6	31
AI innovation drivers			
Talent — 24	🇺🇸	8	31
Research — 19	🇺🇸	6	19
Commercial — 9	🇺🇸	3	14
Development — 8	🇺🇸	7	22
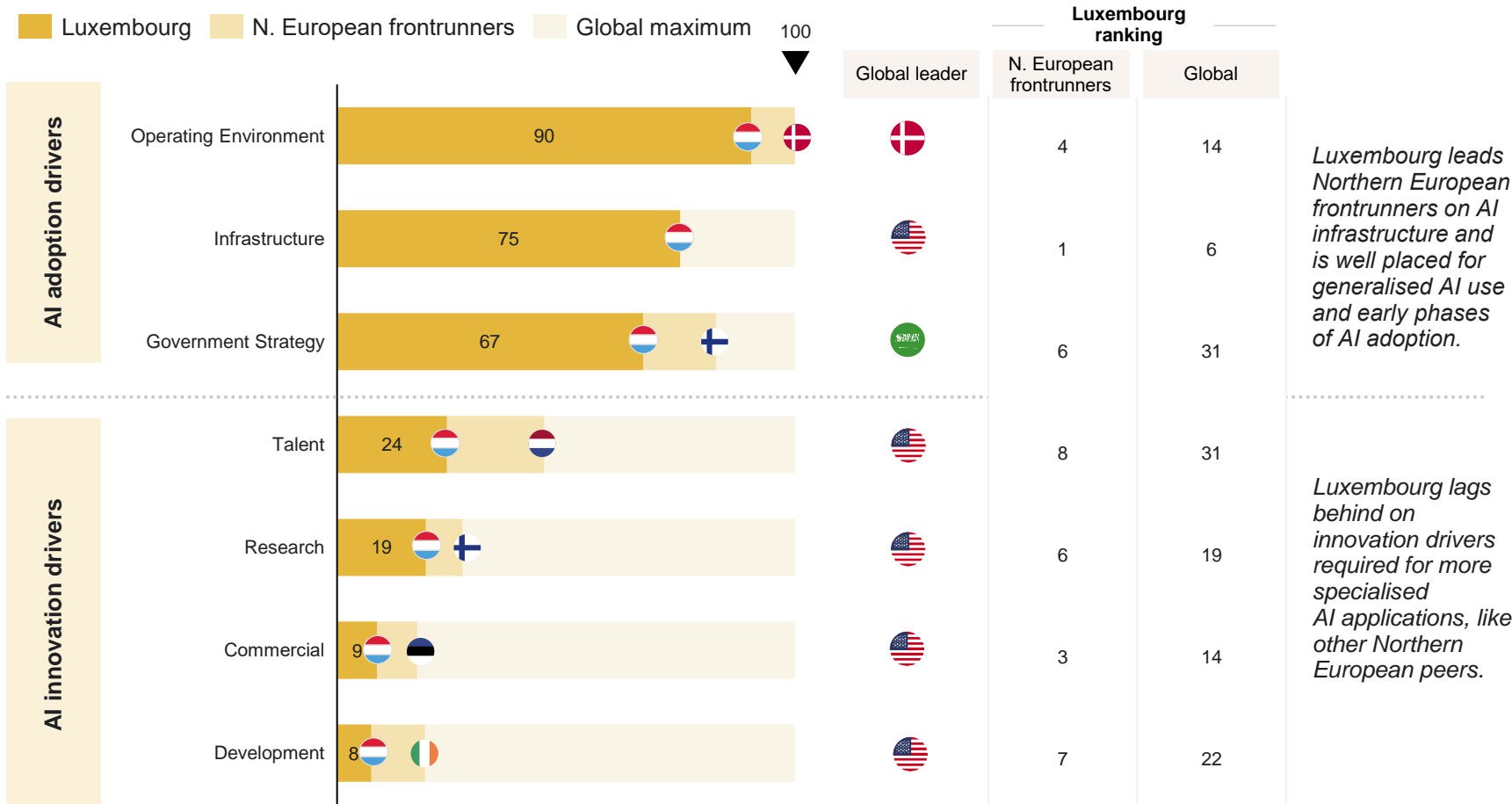
Luxembourg leads Northern European frontrunners on AI infrastructure and is well placed for generalised AI use and early phases of AI adoption.

Luxembourg lags behind on innovation drivers required for more specialised AI applications, like other Northern European peers.

- Luxembourg leads Northern European frontrunners on infrastructure, largely due to its significant supercomputing capacity per capita.

- Luxembourg also performs well on other foundational AI adoption drivers that ensure a safe and reliable AI-ready environment – namely, operating environment and government strategy.

- More specialised AI applications and the realisation of full productivity gains will require a cohesive and competitive innovation ecosystem to foster development and commercial uptake. Luxembourg, as a small country, should focus on strengthening its innovation capacity in the EU/Benelux region.

- Similar to other Northern European frontrunners, Luxembourg lags behind globally on complementary innovations, investments and AI-related skills. Here, the United States is far ahead globally, which is largely due to scale in AI capacity.

- On talent, Luxembourg also lags significantly behind its Northern European peers, which is likely due to its small workforce and limited STEM skills.

- Current gaps suggest that Luxembourg is at risk of losing its frontrunner position and needs to collaborate at the EU/Benelux level to build up talent and R&D capabilities.

Note: The Global AI Index looks at seven sub-pillars for AI capacity: talent (availability of skilled practitioners in AI solutions, including IT and STEM graduates, data scientists, AI professionals etc.), infrastructure (download speed, supercomputing capabilities etc.), operating environment (regulation, cybersecurity etc.), research (AI publications and citations etc.), development (fundamental platforms and algorithms etc.), government strategy (national funding commitments to AI etc.) and commercial ventures (AI start-up activity, investments etc.).
Source: Implement Economics based on Tortoise Media.

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07

The way forward to capture the benefits of AI

Luxembourg can consider several options to capture the benefits and navigate the dilemmas of AI.

Potentials, pitfalls and paradoxes

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AI has the potential to be the most powerful technology in decades

- AI enables us to do things better and work more efficiently. It also enables us to do better things. With AI, we can focus on the best parts of our jobs and leave the rest to AI. Yet, AI is still in its infancy and how it is applied is highly uncertain.
- To make AI benefit humans and society as a whole will require pursuing the potentials, avoiding the pitfalls and navigating the paradoxes.

- The future of AI should *not* be reduced to a simple one-dimensional question: Should we have more AI or less AI – or even ban AI?
- AI is not a fixed thing with a predetermined future that can come quickly or slowly. AI is new, **uncertain** and malleable and will require wise choices by all stakeholders across business, governments and civil society.

Potentials	Pitfalls	Paradoxes
- The estimated economic potential assumes **widespread adoption** of generative AI within ten years. - The estimate includes both narrow **labour-saving** impacts and broader **value-creating** impacts that enable workers to do something novel or powerful. - It assumes that AI lives up to its promise of being the most radical **technological breakthrough** in decades. - Moreover, we estimate that AI will **complement the majority of workers** and free up time to spend on non-routine, creative and inventive tasks. - The result is an economy not simply at a higher level of productivity, but at a **permanently higher growth rate**.	- Displaced workers might end up in **less productive jobs** (than already assumed). - AI may end up being **less promising** or less ready to bring to market than initially hoped. - Time to market may be **challenged by a legal regime** not designed for AI. - Companies may **miss out on the benefits** of AI due to a lack of competences or failing to change organisations and habits. - National regulators, driven by any number of concerns, may **impose strict regulations** that slow the speed of AI development. **Regulatory uncertainty** and lack of clarity on future rules may delay the uptake.	- How can policies encourage the types of AI that complement human labour and best prepare those at risk of losing a job to AI? - What choices will encourage the development of AI that companies of all sizes can access instead of just the largest ones? - What kind of investment in AI research and development might unleash the most interesting new ideas, innovations and applications in support of overall societal value? - What kind of high-performance computer infrastructure is needed to power the new technology and how is that best provided?

Unlocking the AI opportunity by creating trust *and* preserving the incentive to invest

The benefits of new waves of technology do not come automatically. As with past waves of technology, it takes time for people to trust the technology. Regulators across the world are set to ensure the safety of the technology while achieving its benefits. The EU's AI Act aims to lead on this. In the urgent efforts to achieve broad-based trust, regulators may create fragmentation, misalignment and uncertainty about future rules, which can hamper investment and adoption.

Developers and early technology adopters will need clarity on future rules. Clarity is needed regarding, for example, the requirements for transparency in the functioning of the generative AI models, the data used to train them, issues of bias and fairness, potential intellectual property issues, possible privacy violations as well as security concerns.

To navigate these choices, this report offers five perspectives:

Enable innovation and invest in AI research and development	Create a conducive and aligned AI regulation	Promote widespread adoption and universal accessibility	Build human capital and an AI-empowered workforce	Invest in AI infrastructure and compute power
• Invest in long-term public AI research and encourage private investment in basic and applied research at national and EU level. • Foster industry, government and university innovation partnerships to undertake pre-commercial AI research projects. • Support innovation on top of already developed foundational models and findings, e.g. by leveraging the new EU AI innovation package. • Make AI tools available to entrepreneurs and scientists so they can use AI in support of other discoveries and innovations. • Support international research collaboration, technology transfer and international movement of researchers.	• Avoid siloed approaches to AI regulation to minimise the risk of misalignment and fragmentation by increased international co-operation. • Ensure copyright rules that support innovation and creativity and preserve the incentive to generate new content. • Adopt a risk-based approach to AI regulation to provide clarity to developers, adopters and users about which uses are disallowed. • Encourage privacy and security principles so that individuals' personal data is safeguarded.	• Promote widespread adoption and universal accessibility by helping governments, small businesses and all sectors of the economy adopt and use AI. • Lead with the public sector adoption of AI solutions, which may require overcoming procurement roadblocks that often appear when public entities aim to adopt new technologies. • Create a national strategy to spur AI adoption across all industries and all sizes of businesses. • Give small businesses an "AI jumpstart" through technical assistance, training and guidance to help them understand and leverage AI for their businesses.	• Build an AI-empowered workforce by investing in human capital, education and training systems. This means treating AI as a core component of the education system. • Focus training and upskilling on areas where AI enhances and augments the capabilities of workers so that workers are trained to work together with the new technology. The aim should be to improve the marginal productivity of workers rather than replace them. • In those selected types of jobs where AI risks displacing workers, efforts should be devoted to reskilling workers for other jobs. • Ensure a flexible labour market and continuous lifelong training enabling new opportunities in the labour market.	• Ensure the right incentive and regulation for public and private entities to invest in AI infrastructure and compute capacity such as graphics processing and supercomputers needed to drive the powerful AI models. • Enable trusted cross-border data flows in trade agreements and ensure regulatory interoperability and non-discrimination in the EU. • Support the building of cross-border AI infrastructure and subsea cables through initiatives such as the G7 partnership for global infrastructure and investment. • Reduce electricity emissions from data centres by promoting ambitious decarbonisation strategies such as 24/7 Carbon-Free Energy.

Note: For more details on policies, see OECD AI principles, OECD AI Observatory, EU's ethic guidelines for trustworthy AI, EU's AI innovation package, Google's AI principles and paper on "An Opportunity Agenda for AI". For more details on carbon-free energy and digital decarbonisation, see the European perspective and global perspective.

Luxembourg can draw on policy choices of other frontrunners

Luxembourg can draw on policy choices of other Northern European digital frontrunners

Indicator	Development	Operating environment	Infrastructure	Research	Talent	Commercial
Northern European leaders	🇮🇪	🇩🇰	🇫🇮	🇫🇮	🇳🇱	🇪🇪
Best practice	Ireland attracts global tech companies for its **competitive, pro-business environment**, ensuring that innovative researchers, companies and entrepreneurs that are developing and using AI are connected to each other. **Example**: Lero, The SFI Research Centre for Software • Brings together 200 researchers in Ireland, covering a wide range of software development related to AI.	Denmark is a **pioneer in enforcing transparency and ethical use of AI** and has introduced principles and tools to ensure responsible AI deployment. The tools are aimed at building trust in AI technologies. **Example**: Guide for responsible use of generative AI • Formal ethics and safety guidelines for using and implementing AI publicly and privately. • *Datavejviseren:* A platform that provides access to all public data sources. • *Sprogteknologi:* Supports the development of AI solutions in Danish.	Finland is home to one of the **fastest supercomputers** in the world called LUMI. Up to 20% of the LUMI supercomputer's capacity has been reserved for European industry and SMEs, including access to the LUMI user support team, enabling companies to take advantage of high-performance computing for innovation and development activities. **Example:** Poro LLMs • A family of open LLMs built and trained on the LUMI supercomputer. • With its advanced capabilities with low-resource languages, Poro will be built to handle all 24 languages of the EU.	Finland's long track record in AI research is a testament to its **world-renowned universities** offering a variety of AI courses/programmes, active industry-academic collaboration and innovative startups with roots in universities and research. **Example:** AI for Business programme (2018-2021) • Funding targeted for all-sized companies and research institutions for AI R&D projects. • Aimed to increase AI expertise and build global ecosystems and research collaborations.	The Netherlands is nurturing and growing AI **talent through targeted and joint undertakings by industry and research institutions.** **Example:** Kickstart AI • Host AI superchallenges to solve societal issues and promote talent globally. • Create joint industry-academia appointments, adding 25 new positions to enhance education and training. • Promote a national AI course, aiming to reach 170,000 people.	Estonia recognises itself as being an **implementation leader** for startups and AI applications. The national AI strategy (2019) outlines 12 initiatives to accelerate AI uptake in companies, incl. different funding measures and 9 initiatives to increase R&D. **Example:** AI & Robotics Estonia (AIRE) • Supports Estonian industrial companies in adopting smart digital solutions in the field of AI and robotics. • Provides funding and expertise through training and consulting as well as by connecting companies with service providers.

Note: Luxembourg scores highest among the Northern European frontrunners in infrastructure, mainly due to high per capita supercomputing capacity, but we find it more appropriate to refer to Finland (which ranks second among its peers in infrastructure) for best practice.

Increasing the competitive edge in technology and digitalisation requires a balanced set of choices

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Grow R&D by local innovators

Enable **innovation** and invest in AI **research and development**

Accelerate commercial uptake

Promote widespread **adoption** and universal accessibility

Retrain and upskill workforce

Build **human capital** and an AI-empowered workforce

Dilemma

Ensuring performance of AI technology in a Luxembourgish context

and

Driving the application of leading global AI technology

Encouraging AI-based business models in tech-focused startups

and

Facilitating AI adoption in traditional, established companies

General AI upskilling across the population

and

Targeted reskilling of groups affected by AI

Recommendation

- Luxembourg should leverage its strong AI infrastructure and existing research initiatives to form more global partnerships to develop market- leading AI products and deliver on their strategic vision to become part of a cutting-edge, cross-border hub for applied AI research.
- Luxembourg should increase targeted research funding and academia-backed support for AI startups in areas such as finance and healthcare where the country has an advantage, taking inspiration from the successful model of academia-start-up synergy in Amsterdam and Helsinki, among others.

- Despite Luxembourg's frontrunner position in AI adoption across Europe, a discrepancy persists between AI-driven startups and established companies like SMEs. To bridge this gap, policy- makers should increase support for initiatives like the EUREKA AI Clusters, expanding their role in facilitating the integration of AI in SMEs in Luxembourg.
- Building on the strategic foundation laid out in the Luxinnovation Strategy 2022-2025 and leveraging established innovation hubs, policies should aim to create synergies between startups, traditional companies and global partners like NVIDIA in the field of AI to further develop the AI ecosystem.

- Recognising the gaps in AI talent, Luxembourg must address the widespread need for AI knowledge that is crucial for SME uptake as well as the need for specialised STEM knowledge that is essential for innovation and development in the AI sector.
- While several existing programmes focus on developing AI talent in Luxembourg, the country could benefit from an explicit AI strategy like other European peers, facilitating a coherent approach towards an AI-driven transition of the workforce and encompassing scalable AI literacy programmes and intensive STEM specialisation tracks.

Note: For more details on policies, see OECD AI Observatory and Google's policy paper on "AI Opportunity".

08

Annex

Modelling the impacts of generative AI in Luxembourg.

Bibliography

Acemoglu, D., Anderson, G. W., Beede, D. N., Buffington, C., Childress, E. E., Dinlersoz, E. & Zolas, N. (2022). Automation and the workforce: A firm-level view from the 2019 Annual Business Survey (No. w30659). National Bureau of Economic Research.

Alderucci, D., Branstetter, L., Hovy, E., Runge, A., & Zolas, N. (2020, January). Quantifying the impact of AI on productivity and labor demand: Evidence from US census microdata. In Allied social science associations—ASSA 2020 annual meeting.

Andersen, J., Harmsen, O., Rants, K., & Schröder, P. (2023). Det økonomiske potentiale af GenAI i Danmark. McKinsey & Company.

Andrews, D., Nicoletti, G., & Timiliotis, C. (2018). Digital technology diffusion: A matter of capabilities, incentives or both?

Boston Consulting Group. (2024). How AI Can Speed-Up Climate Action. Retrieved from https://www.bcg.com/publications/2023/how-ai-can-speedup-climate-action

Borowiecki, M., Pareliussen, J., Glocker, D., Kim, E. J., Polder, M., & Rud, I. (2021). The impact of digitalisation on productivity: Firm-level evidence from the Netherlands.

Briggs, J., Kodnani, D., Hatzius, J. & Pierdomenico, G. (2023a). The potentially large effects of artificial intelligence on economic growth. Goldman Sachs.

Briggs, J., & Kodnani, D. (2023b). Upgrading our long-run global growth forecasts to reflect the impact of generative AI. Goldman Sachs.

Brynjolfsson, E., Li, D., & Raymond, L. R. (2023). Generative AI at work. National Bureau of Economic Research.

CEDEFOP, European Centre for the Development of Vocational Training, Skills forecast.

Czarnitzki, D., Fernández, G. P., & Rammer, C. (2023). Artificial intelligence and firm-level productivity. Journal of Economic Behavior & Organization, 211, 188-205.

Damioli, G., Van Roy, V., & Vertesy, D. (2021). The impact of artificial intelligence on labor productivity. Eurasian Business Review, 11, 1-25.

Dell'Acqua, F., McFowland, E., Mollick, E. R., Lifshitz-Assaf, H., Kellogg, K., Rajendran, S. & Lakhani, K. R. (2023). Navigating the jagged technological frontier: Field experimental evidence of the effects of AI on knowledge worker productivity and quality. Harvard Business School Technology & Operations Mgt. Unit Working Paper, (24-013).

European Commission. (2023). Commission staff working document – Digital Decade Cardinal Points.

European Commission. (2024). Commission launches AI Innovation Package to support artificial intelligence startups and SMEs. Retrieved from https://digital-strategy.ec.europa.eu/en/news/commission-launches-ai-innovation-package-support-artificial-intelligence-startups-and-smes

European Commission. (2024). Ethics guidelines for trustworthy AI. Retrieved from https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai

Gal, P., Nicoletti, G., Renault, T., Sorbe, S., & Timiliotis, C. (2019). Digitalisation and productivity: In search of the holy grail–Firm-level empirical evidence from EU countries.

Google AI. (2024). Google AI Principles. Retrieved from https://ai.google/responsibility/principles/

Google. (2023). The Google AI opportunity agenda. Google. Retrieved from https://blog.google/outreach-initiatives/public-policy/google-ai-opportunity-agenda/

Healthcare IT News. (2019). Luxembourg hospital group to pilot AI radiological image analysis solution. Retrieved from: https://www.healthcareitnews.com/news/emea/luxembourg-hospital-group-pilot-ai-radiological-image-analysis-solution

Implement Consulting Group. (2024). Digital Decarbonisation. Retrieved from https://implementconsultinggroup.com/article/digital-decarbonisation

Ipsos & Google. (2024). Multi-country AI survey.

Jiang, Z., Xu, F., Araki, J. and Neubig, G. (2020). How Can We Known What Language Models Know? Transactions of the Association for Computational Linguistics.

Luxinnovation. (2022). National Research and Innovation Strategy for Luxembourg 2022-2025. Retrieved from https://www.luxinnovation.lu/wp-content/uploads/sites/3/2022/01/10566_li_strategie2022_en_web.pdf

Malmodin, J. & Bergmark, P. (2015). Exploring the effect of ICT solutions on GHG emissions in 2030, paper for 29th International Conference on Informatics for Environmental Protection, EnviroInfo 2015 (Ericsson Research).

Markets 360. (2023, November 09). The global economic impact of AI. BNP Paribas Global Markets. Retrieved from https://globalmarkets.cib.bnpparibas/the-global-economic-impact-of-ai/.

Medical Device Network. (2023). [Countryish] hospital trials AI app to monitor for heart failure. https://www.medicaldevice-network.com/news/[Countryish]-hospital-trials-ai-app-to-monitor-for-heart-failure/

Ministry of Economy, Trade and Business. (2019). National Strategy for Artificial Intelligence. Luxembourg.

Mosiashvili, N., & Pareliussen, J. (2020). Digital technology adoption, productivity gains in adopting firms and sectoral spill-overs: Firm-level evidence from Estonia.

Noy, S., & Zhang, W. (2023). Experimental evidence on the productivity effects of generative artificial intelligence. Science, 381(187-192). https://doi.org/10.1126/science.adh2586

OECD. (2019). In-Depth Productivity Review of Luxembourg. OECD Publishing, Paris.

OECD. (2022). Measuring the environmental impacts of artificial intelligence compute and applications: The AI footprint (OECD Digital Economy Papers No. 341).

OECD. (2024). AI Principles Overview. Retrieved from https://oecd.ai/en/ai-principles

OECD. (2024). Generative AI for SMEs: Separating the Chit and the ChatGPT - Key Highlights.

OECD/European Observatory on Health Systems and Policies. (2023). Luxembourg: Country Health Profile 2023, State of Health in the EU.

Ouyang, L., Wu, J., Jiang, X., Almeida, D., Wainwright, C., Mishkin, P. & Lowe, R. (2022). Training language models to follow instructions with human feedback. Advances in Neural Information Processing Systems, 35, 27730-27744.

Public First. (2023). Views on AI from Europe's businesses: Attitudes to AI in travel, energy, retail, financial services & automotive.

PwC. (2023). The 2023 Luxembourg outlook on PwC's Hopes & Fears survey. Retrieved from https://www.pwc.lu/en/people-organisation/hopes-and-fears-2023.html.

Rammer C., Fernández, G. P., & Czarnitzki, D. (2022). Artificial intelligence and industrial innovation: Evidence from German firm-level data. Research Policy, 51(7), 104555.

Salesforce & YouGov. (2023). More than Half of Generative AI Adopters Use Unapproved Tools at Work. Retrieved from https://www.salesforce.com/au/news/stories/ai-at-work-research/

Soni, V. (2023). Impact of Generative AI on Small and Medium Enterprises' Revenue Growth: The Moderating Role of Human, Technological, and Market Factors. Reviews of Contemporary Business Analytics, 6(1), 133-153.

The White House. (2024). FACT SHEET: Partnership for Global Infrastructure and Investment at the G7 Summit. Retrieved from https://www.whitehouse.gov/briefing-room/statements-releases/2023/05/20/fact-sheet-partnership-for-global-infrastructure-and-investment-at-the-g7-summit/

Tortoise Media (2023). The Global AI Index. https://www.tortoisemedia.com/intelligence/global-ai/.

VLAIO. (2024). Waarom met Artificiële Intelligentie aan de slag? Retrieved from https://www.vlaio.be/nl/begeleiding-advies/digitalisering/artificiele-intelligentie/waarom-met-artificiele-intelligentie/ai

Zhai, S., & Liu, Z. (2023). Artificial intelligence technology innovation and firm productivity: evidence from China. Finance Research Letters, 58, 104437.

Modelling the economic opportunity for Luxembourg

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Overview of the methodological approach to calculating economic growth and productivity impact from generative AI

The economic effects are calculated in the following steps

1   **Automation potential of work activities:** First, the exposure to generative AI is calculated by breaking down the automation potential of 39 different work activities/tasks in the occupational task database O*NET. The database includes an estimate of the share of each activity (e.g. getting information, performing administrative activities etc.) that can be automated by generative AI (if the activity is above level 4 on an O*NET-defined scale of difficulty 1-7, no automation potential is assumed).

2   **Mapping automation potential of work activities to occupations:** The automation potential of the work activities is mapped in ten European industry aggregates in two sub-steps. First, the 39 work activities for 900 US occupations are mapped using importance-average activities for each occupation, providing an estimate of the share of each occupation's total workload that AI has the potential to automate. Secondly, this number is projected from US to European occupations through the European Commission's crosswalk between ESCO and O*NET and finally compiled into aggregated occupations (using the sub-occupation employment). This leaves us with the three shares that describe how big a share of the work activates for each occupation is expected to see: No automation, AI complement and Likely replacement.

3   **Quantifying productivity gains in each sector:** Generative AI is assumed to affect the productivity of the work activities for each occupation as follows (see section 3 for further details). The "No automation" share of work activities is assumed to be unaffected by generative AI. "AI complement" work activities experience a productivity boost from automation. "Likely replacement" is the share of work activities in a sector that is expected to be entirely automated/replaced. These workers are expected to be re-employed in slightly less productive jobs. The three effects are calculated across sectors and scaled by each sector's value added to determine the full productivity potential/generation of new jobs from generative AI across the economy, once the technology adoption peaks.

4   **Aggregate GDP impact:** Based on the estimated increase in labour productivity resulting from AI adoption, the result is aggregated to an overall GDP. Only part of the total long-run productivity increases from generative AI is expected to materialise in the economy during the initial ten-year period of technology adoption following an S-curve adoption trajectory.

- The method used to calculate productivity and GDP effects of generative AI in this paper is in line with the methodology developed by Briggs and Kodnani (2023) in "The Potentially Large Effects of Artificial Intelligence on Economic Growth".

Note: Methodology is based on Briggs and Kodnani (2023a).
Source: Implement Economics based on the European Commission, Eurostat, O*Net and Briggs and Kodnani (2023a).

Disclaimer

This report (the "Report") has been prepared by Implement Consulting Group (Implement).
The purpose of this Report is to assess the economic opportunity of generative AI in Luxembourg.

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