Annex

Summary

The State of Compute Access data explorer measures the computing ecosystem maturity of countries around the world. It covers 55 countries, measuring them against 25 indicators. These indicators are split into seven categories:

- Compute capacity
- Connectivity and infrastructure
- Software and programming
- Investment
- Local talent pool
- Sustainability and resilience
- Policy and governance

The following overview of each indicator details data source, the method used to transform data into a measurable indicator and the metric displayed in the index. To provide maximum value we have adhered to some guiding principles while preparing the index:

1. For all indicators based on an annual recurring metric, 2022 has been used as the baseline year. Where the metric is a snapshot in time, such as availability of a service or solution, the snapshot has been taken within the first half of 2023 and can reflect launched services and solutions within that period.

2. While we use 2022 as the base period in the index, we have been able to build a historic database for many of the indicators, including local supercomputing capacity and investment in high-technology goods and services.

3. Data sources that minimise reporting gaps have been selected but this was not possible in the case of six indicators. This was driven by a lack of reporting from select countries to institutions such as the OECD and the World Bank. For Russia specifically we have been unable to build an indicator for data-governance policy and found it difficult to corroborate data points where reporting exists, due to verification difficulty. The six indicators with data gaps are:

    a. Power-grid maturity has data gaps for ten countries: Australia, Canada, Japan, Norway, Saudi Arabia, Singapore, Taiwan, UAE, the UK and the US

    b. Relative supply to demand for software engineers has data gaps for 20 countries: China, Croatia, Ethiopia, Ghana, India, Indonesia, Israel, Japan, Kenya, Mauritius, Morocco, Nigeria, Russia, Rwanda, Saudi Arabia, Senegal, Singapore, South Korea, Taiwan and UAE

    c. Investment in high technology has data gaps for nine countries: Croatia, Estonia, Ethiopia, Latvia, Lithuania, Luxembourg, Mauritius, Rwanda and Slovakia

    d. R&D incentives has data gap for 13 counties: Ethiopia, Ghana, India, Indonesia, Kenya, Mauritius, Morocco, Nigeria, Rwanda, Saudi Arabia, Senegal, Taiwan and UAE

    e. STEM-graduates share has data gaps for seven countries: China, Ethiopia, Japan, Kenya, Nigeria, Senegal and Taiwan

    f. Compute patents has data gap for seven countries: Ethiopia, Ghana, Mauritius, Rwanda, Senegal, South Korea and Taiwan

4. We have purposefully focused on the investment of key market makers, such as the buildout of data centres by leading cloud-service providers Amazon, Google, Microsoft, Oracle and so on. These companies lead the market from the perspective of portfolio comprehensiveness and time to market, enabling early access to new compute hardware and software.

Compute capacity

Compute capacity is the foundational indicator category in this index. It is built using a mixture of proprietary Omdia data and third-party data (with links to the source provided below). The former is based on data directly provided to Omdia by key market players, or collected by Omdia using a mixture of public sources and private interviews. Omdia measures general-purpose and specialised computing capacity, and the pace of change, using six key indicators.

1. **Server installed base** looks at the number of deployed servers in a country.

    a. Source: Omdia's Data Center Server Tracker and Data Center Building Tracker. To populate the first tracker, Omdia collects server-shipments data directly from original equipment manufacturers and original design manufacturers by country, and verifies the reports using processor-shipments guidance provided by the largest semiconductor suppliers. This information is then applied to useful-life data gathered through data-centre operator interviews and surveys. For maximum accuracy, the installed base is cross-checked with Omdia's data-centre building trackers, which cover the number and size of data centres in each country.

    b. Methodology: Omdia's useful-life analysis and, therefore, installed-base estimation considers server refurbishment, which became more common in 2020 when the semiconductor shortage prolonged order-fulfilment times.

    c. Metric: Absolute number of deployed servers.

2. **Server installed base per capita** expands on the first indicator, by comparing the number of deployed servers to each country's population.

    a. Source: The source for population data is S&P Global (previously IHS Markit).

    b. Methodology: Calculated by dividing the number of deployed servers in each country by one-thousandth of its population.

c. Metric: Absolute number of servers per 1,000 people.

3. **Server-investment growth** measures upcoming server deployments. This forecast-based indicator is a third-party analyst opinion and, as with any market prediction, is subject to error due to unforeseen changes in market conditions.

    a. Source: Statista market insights.

    b. Methodology: Calculated by taking an average of each country's short-term server shipment growth and five-year compound aggregate growth rate (CAGR).

    c. Metric: Average of the server shipment growth in 2022 and 2023, and the five-year CAGR, multiplied by a factor of ten.

4. **Local supercomputer capacity** measures the number of supercomputers in each country.

    a. Source: TOP500 and secondary research.

    b. Methodology: Takes into account the number of supercomputers in each country within the TOP500 supercomputer list and the total floating-point operations per second (TFLOPs) of these supercomputers in each country. After awarding points for total number of supercomputers and total number of TFLOPs in the TOP500 supercomputer list, Omdia calculates an average score. This approach was chosen to recognise the value in both a distributed network of supercomputers and the value a smaller number of high-performance supercomputers. Countries that started investing in supercomputing infrastructure more recently are likely to have a smaller number of high-performance supercomputers because they are built using the latest processors, which boast superior performance. For countries with supercomputers that did not make it into the TOP500 supercomputer list, Omdia has awarded points for existing installations and for announcements of new installations.

    c. Metric: Points awarded as follows:

NUMBER OF SUPERCOMPUTERS IN THE TOP500 LIST	POINTS AWARDED
0	0
1	10
2 to 4	20
5 to 7	30
8 to 10	40
11 to 14	50
15 to 19	60
20 to 29	70
30 to 49	80
50 to 99	90
100 or more	100

SUPERCOMPUTER TFLOP PERFORMANCE	POINTS AWARDED
0	0
1 to 9,999	10
10,000 to 29,999	20
30,000 to 39,999	30
40,000 to 49,999	40
50,000 to 99,999	50
100,000 to 199,999	60
200,000 to 299,999	70
300,000 to 499,999	80
500,000 to 999,999	90
1,000,000 or more	100

- For countries not featured in the TOP500 supercomputer list, five points have been awarded for at least one pre-existing supercomputer. Countries have received five points regardless of the number of supercomputers not featured in the list.

- Five points have been awarded for an announced supercomputer in a country.

- Omdia has capped the maximum score at 100. The US and China would have scored more than 100 if the cap was not in place.

5. **Access to parallel computing** looks at cloud services optimised for artificial intelligence (AI) and machine-learning techniques available from the top-three cloud-service providers.

    a. Source: The data was obtained from the cloud-service providers' respective websites: AWS, Google and Microsoft.

    b. Methodology: Calculated by checking if AWS, Google and Microsoft provide a cloud service optimised for machine learning inside each country. Points were distributed based on the number of providers present in each country.

    c. Metric: Using an additive system, each cloud-service provider in each country resulted in an award of 33.333 points, enabling a maximum score of 100 per country.

6. Access to quantum computing measures the number of institutions in each country that have announced/reported that they are using quantum computing (either an installed quantum computer or a cloud simulation).

    a. Source: Omdia's Quantum Computing Market Tracker, published in August 2023, which features data on 158 institutions that have adopted quantum computing. Analysts rely on adoption announcements, making the dataset subject to data gaps.

    b. Methodology: Based on the total number of quantum-computing institutions.

    c. Metric: Number of academic institutions with access to quantum computing.

Connectivity and infrastructure

This group of indicators measures the infrastructure that can impact or drive compute-capacity expansion.

7. **Power-grid maturity** measures the reliability of a county's power grid over a given year.

    a. Source: The World Bank and NationMaster. The two-source approach was chosen to increase accuracy and eliminate as many data gaps as possible.

    b. Methodology: The indicator was calculated by taking an average of the power-outage days per country from the two data sources.

    c. Metric: Average annual number of power-outage days per country.

8. **Subsea cable landing and internet exchange** measure a country's connectivity.

    a. Source: The Submarine Cable Map website. The internet-exchange data was obtained from the Data Center Map website.

b. Methodology: Calculated by taking the average of two metrics: the number of subsea cables with connection points to each country, and each country's total internet exchanges.

c. Metric: Average of the number of subsea cables and the number of internet exchanges in a country, with a cap of 100. The US and Indonesia would have scored more than 100 had the maximum not been capped.

9. **Cloud-service availability** measures a country's access to cloud services using the number and size of data centres operated by the top 41 cloud and co-location companies. This measure was chosen because it provides a high-accuracy insight into the availability of industry-leading cloud services.

   a. Source: Data Center Building Tracker, which covers all data centres for the 41 largest cloud and co-location data-centre operators. These 41 companies represent more than 50 per cent of the global data-centre power capacity and are building at the fastest rate in the industry.

   b. Methodology: Average of the number of cloud and co-location data centres in a country and size of the data centres (space measured in square feet), represented per capita x105. The square-feet measure was chosen in addition to the data-centre count to give credit to less distributed environments, where there are fewer but larger data centres in a country. This can often be the case in a quickly developing market. Representing the metric per capita is intended to provide context for the demand of a country.

   c. Metric: Points awarded as follows (based on average of the two indicators):

CLOUD AND CO-LOCATION DATA-CENTRE SPACE (SQUARE FEET) PER CAPITA	POINTS AWARDED
0	0
1 to 10	10
11 to 2,499	20
2,500 to 4,999	30
5,000 to 9,999	40
10,000 to 14,999	50
15,000 to 19,999	60
20,000 to 24,999	70
25,000 to 49,999	80
50,000 to 94,999	90
95,000 or more	100

CLOUD AND CO-LOCATION DATA-CENTRE COUNT	POINTS AWARDED
0	0
1	10
2 to 4	20
5 to 7	30
8 to 10	40
11 to 14	50
15 to 24	60
25 to 49	70
50 to 99	80
100 to 399	90
400 or more	100

10. **Relative supply to demand for software engineers** measures the quality and quantity of the software engineers compared to a country's need for those specific skills.

    a. Source: The OECD skills-need-by-country data set. Omdia chose only two data points from the overall OECD dataset: "computer programming" and "web development and cloud technologies". An analysis of the overall OECD data set is available in a dedicated report by the OEDC.

    b. Methodology: Omdia took an average of the score per country for "computer programming" and "web development and cloud technologies" skills.

    c. Metric: A decimal score, which is positive if the supply is greater than the demand and skill of the local population, negative if the demand and skill are greater than a country's supply.

11. **Software engineering professionals in each country** is an indicator that takes into account the total number of suitably skilled professionals in a country.

    a. Source: LinkedIn.

    b. Methodology: The total number of software engineers was calculated using LinkedIn.

    c. Metric: Total number of software engineers in each country.

12. **Participation in the open-source community** looks at the total number of contributions to GitHub from each country.

    a. Source: GitHub.

    b. Methodology: Calculated by taking a country's total number of public and private contributions to GitHub across all users. The developer who prepared the programme to retrieve this data states that only the top 1,000 contributors from each country are captured by default, but all 55 countries tracked in this index have fewer than 1,000 GitHub contributors.

    c. Metric: Total number of Github contributions per country.

13. **Investment in high technology** looks at a country's spending on high-technology goods and services as a share of GDP.

    a. Source: S&P Global, previously IHS Markit, using primary and secondary research.

    b. Methodology: The indicator uses a country's total ICT capital expenditure and divides it by the nominal GDP to obtain a percentage.

    c. Metric: Percentage of total ICT spending in relation to that country's GDP.

14. **Data-centre investment** looks at the announced data-centre building activity by the top 41 cloud and co-location service providers. These companies are responsible for the majority of global data-centre building activity and are expanding at a very fast pace. This measure was chosen because of the significance of these companies entering a market: their data centres tend to incorporate the most innovative design and operations practices. For example, the efficiency of the data centres operated by Amazon, Google, Meta and Microsoft is significantly higher than that of an average enterprise-data-centre builder. For a more comprehensive approach, Omdia also recorded announced data-centre activity for countries where the top 41 companies are not planning to build a data centre yet.

    a. Source: Omdia's Data Center Building Tracker and new secondary research.

    b. Methodology: Calculated by averaging the number of announced data-centre builds in each country and the total number of kilowatts (kW) capacity this will contribute once completed, both converted to points using the below allocation. This approach was chosen to recognise the significance of larger data centres, in terms of expanding compute capacity quickly. For countries not covered in Omdia's Data Centre Building Tracker, five points were given for any new data-centre building-activity announcement.

c. Metric: Points awarded as follows (based on average of the two indicators):

NUMBER OF ANNOUNCED DATA CENTRES UNDER CONSTRUCTION (FOR TOP 41 CLOUD AND CO-LOCATION COMPANIES)	POINTS AWARDED
0	0
1	10
2 to 3	20
4 to 6	30
7 to 9	40
10 to 14	50
15 to 19	60
20 to 29	70
30 to 49	80
50 to 99	90
100 or more	100

ANNOUNCED DATA-CENTRE CAPACITY UNDER CONSTRUCTION (KW)	POINTS AWARDED
0	0
1	10
2 to 3	20
4 to 6	30
7 to 9	40
10 to 12	50
13 to 15	60
16 to 18	70
19 to 21	80
22 to 29	90
30 or more	100

- Five points have been awarded to countries where none of the top 41 cloud and co-location companies have announced intent to build a new data centre, but at least one other company has made an announcement.

15. **R&D incentives** are a country's monetary initiatives for technology projects.

a. Source: OECD.

b. Methodology: Calculated by taking the average of the country's GERD (gross domestic expenditure on R&D at current PPP) and the effective tax rate for technology R&D, both converted to points.

c. Metric: Points awarded as follows (based on average of the two indicators):

GERD AT CURRENT PPP ($ USD)	POINTS AWARDED
Below $2,499	0
$2,500 to $4,999	10
$5,000 to $9,999	20
$10,000 to $14,999	30
$15,000 to $19,999	40
$20,000 to $24,999	50
$25,000 to $29,999	60
$30,000 to $74,999	70
$75,000 to $99,999	80
$100,000 to $149,999	90
$150,000 or more	100

EFFECTIVE TAX RATE (%) FOR TECHNOLOGY R&D	POINTS AWARDED
22 or more	0
20.1 to 21.9	10
17.1 to 20	20
15.1 to 17	30
13.1 to 15	40
10.1 to 13	50
7.1 to 10	60
5.1 to 7	70
3.1 to 5	80
1.6 to 3	90
1.5 or less	100

16. **Quantum-computing investment** looks at the announced private- and public-sector investment into quantum-computing operations.

    a. Source: Omdia's Quantum Computing Market Tracker using secondary research. An Omdia analyst reviews between 200 and 300 quantum-computing investment announcements every month to complete this tracker.

    b. Methodology: Calculated by taking an average of private- and public-sector investments, both converted to points.

    c. Metric: US dollars (millions).

17. **STEM graduates share** is the percentage of STEM (science, technology, engineering and mathematics) students graduating at university level out of the total graduating student population.

    a. Source: OECD, World Bank, Unesco and Statista.

    b. Methodology: Calculated by taking the percentage of STEM students graduating at university level out of the total graduating student population.

    c. Metric: Percentage of total graduates.

18. **Availability of training programmes** is a country's access to tech education provided by industry leaders. To best represent the mix of skills required by compute professionals, a mix of large cloud-service providers and IT hardware and software companies was included. In the below description we refer to these companies as training leaders.

    a. Source: Training leaders' websites, namely AWS, HPE, Linux, Microsoft and Red Hat.

   b. Methodology: Calculated by taking the average of two metrics. First, the average number of partners that each training leader has in each country; second, whether each training leader runs a training programme in a country's local language. Both the metrics were converted to points.

   c. Metric: Twenty points were awarded for the presence of a training leader (maximum of 100). The same scoring system was applied to the availability of programmes in a local language.

19. **Availability of renewable energy** shows a country's renewable-energy provision as a percentage of total energy usage.

   a. Source: IEA.

   b. Methodology: Calculated by calculating the use of renewable energy as a percentage of a country's total energy usage.

   c. Metric: Percentage of the country's total energy usage.

20. **Sustainability incentives** reflects spending on low-carbon electricity in comparison to GDP.

   a. Source: IEA.

   b. Methodology: Calculated by dividing a country's spend on low-carbon electricity by its total GDP.

   c. Metric: Presented as a percentage.

21. **Compute patents** is the number of technology patents as a proportion of a country's labour force.

   a. Source: OECD.

   b. Methodology: Calculated by taking the number of technology patents filed by citizens of each country, then dividing it by one-millionth of the labour force to give the most legible numbers.

   c. Metric: Patents per million of the labour force.

22. **Ecosystem differentiation** examines the maturity of a local computing ecosystem by looking at the presence of global IT, cloud and data-centre industry leaders in each country.

    a. Source: Omdia's Data Center Server Tracker and Data Center Building Tracker, and additional new secondary research.

    b. Methodology: Calculated by adding up the total number of data-centre operators present in a country, and the total number of server providers in each country.

    c. Metric: One point was awarded for each unique data centre-operator or server provider in each country, with the metric presented as the sum of all points.

23. **Data-governance policy** is the ability of a country to safeguard information using standards and regulations.

    a. Source: Each country's website, CNIL and Open Data Watch's Open Data Inventory.

    b. Methodology: Calculated by taking the average of three metrics: the presence of a data strategy; the sophistication of data-protection regulation; and open data scores. The latter are based on whether data can be downloaded in machine-readable and non-proprietary formats and are accompanied by metadata; also considered is whether download options exist, such as bulk download and user-selection or APIs, and if they have an open terms of use or a data licence.

    c. Metric: An average out of 100 was calculated as a result of scoring of the three datapoints. Data was collected by awarding 100 or zero points based on whether a country has a data strategy or data-protection regulation, and depending on their overall open-data policies.

24. **AI strategy and policy** is the measure of governmental focus on building dedicated computing and AI strategy and policy.

    a. Source: The OECD, the European Commission and each country's AI website (if present).

    b. Methodology: Calculated based on whether a country has an AI strategy, an AI government academic resource, legislation to monitor AI bodies and legislation that mentions generative AI.

    c. Metric: 100 or zero points were awarded based on the presence of an AI strategy, an AI government academic resource, legislation to monitor AI bodies and legislation that mentions generative AI. Final score was calculated by averaging these four metrics.

25. **Tax policy** is a measure of the tax placed on Information and Communications Technology (ICT).

    a. Source: E&Y.

    b. Methodology: Calculated by taking the VAT rate from the sale of ICT products.

    c. Metric: Percentage of VAT for ICT products.