SEIZING THE ER&D ADVANTAGE
FRONTIERS FOR 2030

Global Landscape of Engineering Research & Development
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Our diverse, global teams bring deep industry and functional expertise and a range of perspectives that question the status quo and spark change. BCG delivers solutions through leading-edge management consulting, technology and design, and corporate and digital ventures. We work in a uniquely collaborative model across the firm and throughout all levels of the client organization, fuelled by the goal of helping our clients thrive and enabling them to make the world a better place.

The National Association of Software and Services Companies (NASSCOM) is the premier trade body and chamber of commerce of the Tech industry in India and comprises over 3000-member companies. Our membership spans across the entire spectrum of the industry from startups to multinationals and from products to services, Global Capability Centres to Engineering firms. Guided by India’s vision to become a leading digital economy globally, NASSCOM focuses on accelerating the pace of transformation of the industry to emerge as the preferred enablers for global digital transformation. Our strategic imperatives are to reskill and upskill India’s IT workforce to ensure that talent is future-ready in terms of new-age skills, strengthen the innovation quotient across industry verticals, create new market opportunities - both international and domestic, drive policy advocacy to advance innovation and ease of doing business, and build the industry narrative with focus on Talent, Trust and Innovation. And, in everything we do, we will continue to champion the need for diversity and equal opportunity.
When we first conceptualized the idea of this report, one question was top of mind: How will India’s Business ER&D sourcing market share shape up in 2030? While India is currently doing well in this space, will it continue to grow? Or will a known (or yet unknown) competitor leapfrog India to become a preferred sourcing destination?

After weeks of industry discussions, a global survey spanning 280+ industry executives and endless late-night brainstorming sessions, we can sum up the answer in one statement: India’s future looks bright. For 2 precise reasons – No other country can compete with the scale of India’s Engineering talent, and the possibility to leverage existing relationships Indian firms have been able to put in place with work done in the past.

India is expected to increase share of Global ER&D sourcing market to 22% (2030) vs 17% in 2023. There are several factors at play here, some in India’s favor (e.g. – decline in working age populations across several developed countries) and others that will need attention of all stakeholders, like building a global branding story for Indian ER&D. Ultimately, the country that is able to collectively pivot their service offerings (For e.g. – upskill in Digital engineering, or acquire/develop niche skills in specialized areas like Electric Vehicles platform development) will be able to garner disproportionate share of future spends.

In this report, we address each factor at play, and chart out the road ahead for India, including future ER&D opportunities in specific sectors and geographies that Indian firms can target. We have also identified the specific skillsets that will be in demand from each sector.

There were some great learnings on the road to writing this report, and we hope you enjoy the ride reading this report as much as we did!
EXECUTIVE SUMMARY (I/II)

1. OVERALL ER&D INTENSITY IS INCREASING ACROSS SECTORS; WE EXPECT TO SEE A SUSTAINED UPTICK LEADING TO ER&D SPEND OF $3T BY 2030 (CURRENTLY ~$1.8T)
   - Resurgence of AI, digital imperative across sectors will drive industry at ~9% CAGR in ER&D spend till 2027
   - Beyond 2027, growth is expected to accelerate marginally (~10% CAGR), driven by increasing digital spend and sophistication of digital needs (AI@scale, 6G rollout, etc.)
   - As digital engineering drives the accelerated spend, few sectors will see a disproportionate rise in share of digital engineering spend – Automotive, Industrials, Energy, Utilities and Oil & Gas

2. WHILE TRADITIONAL SECTORS (AUTOMOTIVE, SOFTWARE AND HEALTHCARE) WILL DRIVE 50% OF ER&D SPEND, HIGH-GROWTH SECTORS LIKE TELECOM, SEMICONDUCTORS AND INDUSTRIALS WILL BE IMPORTANT FOCUS AREAS
   - Traditional sectors will spend on fresh sector-specific themes (EVs, telemedicine etc.) to drive $1.5T of ER&D spend
   - New high-growth sectors like telecom (11% CAGR), Semiconductors (10% CAGR) and Industrials (9% CAGR) will mandate a relook at India’s strategic areas of focus, reassess talent needs and refresh policies & regulations landscape

3. US IS THE LARGEST ER&D SPENDER ($550B+), BUT SIX NEW MARKETS ACROSS EU & APAC HAVE EMERGED
   - In EU, Germany, UK, France and Nordics spend $250B+, while Japan and S.Korea spend ~$275B on ER&D
   - But ESPs and GCCs haven’t enjoyed same level of success in these markets, as they have in the US
4. **A LARGE SHARE OF ER&D WILL BE HQ-LED BUT NEARLY 25% ER&D SPEND IS EXPECTED TO BE SOURCED (VIA GCCS OR ESPS) LEADING TO SHARP RISE IN THE ER&D SOURCING MARKET FROM ~$280B TO ~$775B IN 2030**
   - Emerging from the aftermath of the pandemic and war, as companies focus on resilience and agility, ER&D sourcing outside of HQ locations will gain momentum
   - Cost dynamics and access to new-age, digital-ready talent will continue to drive sourcing decisions

5. **THOUGH INDIA DOES FACE COMPETITION FROM OTHER COUNTRIES, IT WILL CONTINUE TO REMAIN A KEY SOURCING DESTINATION AS THESE COUNTRIES WILL NOT BE ABLE TO SERVICE ALL THE DEMAND**
   - Vietnam is well positioned to capture share in large, traditional sectors (Software, Automotive) while other locations like Thailand (Automotive, Energy & Utilities, Oil & Gas), Bulgaria (Industrials), Turkey (Consumer electronics) and Philippines will compete in targeted sectors
   - Nearshore ER&D centers have gained prominence, with locations like Poland, Mexico and Malaysia being some of the preferred locations

6. **TO REMAIN COMPETITIVE, INDIA MUST FOCUS ON THREE KEY IMPERATIVES - GREATER POLICY SUPPORT AND INFRASTRUCTURE IMPROVEMENT, BRANDING & PROMOTION AND SKILL DEVELOPMENT**
   - Incentivizing sectoral leaders to shift larger share of design and R&D work to India (e.g. Design linked incentives) and infrastructure support to setup digital engineering innovation hubs and ER&D industry labs
   - Organizing ER&D capability roadshows, digital expo and participating in marquee sectoral events (MWC, CES) to promote India as a competitive destination
   - Inculcate ER&D related skills in colleges through curated curriculum and incorporate industry inputs into national R&D initiatives (like National Research Foundation)
### Glossary of Key Terminology

<table>
<thead>
<tr>
<th>Terminology</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>ER&amp;D Intensity</td>
<td>Percentage of company’s revenue spent on ER&amp;D</td>
</tr>
<tr>
<td>Business ER&amp;D Spend</td>
<td>Absolute $ spend on ER&amp;D activities of the company; ER&amp;D Intensity X Revenue of the Company. This excludes Govt. R&amp;D spends</td>
</tr>
<tr>
<td>ER&amp;D Sourcing</td>
<td>Business ER&amp;D spend through GCCs and ESPs</td>
</tr>
<tr>
<td>Sourcing %</td>
<td>Share of ER&amp;D Sourcing as part of Business ER&amp;D Spend</td>
</tr>
<tr>
<td>GCC</td>
<td>Global Capability Centres</td>
</tr>
<tr>
<td>ESP</td>
<td>Engineering Service Provider companies</td>
</tr>
<tr>
<td>Digital Engineering</td>
<td>Refers to work involved in building smart, connected, and intelligent products by using digital technology as the backbone (Software, Data &amp; analytics and Embedded systems)</td>
</tr>
<tr>
<td>% Digital Engineering</td>
<td>Spend on digital engineering as a % of Business ER&amp;D spend</td>
</tr>
<tr>
<td>Aerospace &amp; Defence</td>
<td>Includes Aerospace &amp; Defence R&amp;D, Aerospace and Defence Maintenance and Services (MRO), Aero Transportation systems, Aircraft systems, Passenger and Cargo Aircraft and Airplanes, Components &amp; equipment, Rockets and subsystems, Space structure and components, Comms. Satellite</td>
</tr>
<tr>
<td>Automotive</td>
<td>Includes Automobile manufacturers, auto components, and auto ancillary industries</td>
</tr>
<tr>
<td>Consumer Electronics</td>
<td>Includes Consumer electronics, Technology, Hardware, Storage and Peripherals, Household appliances</td>
</tr>
<tr>
<td>Energy, Utilities and Oil &amp; Gas</td>
<td>Includes Integrated O&amp;G, O&amp;G refining and marketing, O&amp;G exploration and production, O&amp;G storage and transport, O&amp;G drilling, Electric utilities, Gas utilities, Power producers and traders, Renewable Electricity</td>
</tr>
<tr>
<td>Healthcare &amp; Medical Devices</td>
<td>Includes Pharmaceuticals, Biotechnology, Healthcare Technology, Medical devices; excludes Payers &amp; Providers, Healthcare supplies &amp; services</td>
</tr>
<tr>
<td>Industrials including Construction</td>
<td>Includes Construction and Engineering, Construction Machinery and Heavy Transportation Equipment, Industrial Machinery and Supplies and Components; excludes on-highway</td>
</tr>
<tr>
<td>Semiconductors</td>
<td>Includes Semiconductor, Semiconductor design and manufacturers</td>
</tr>
<tr>
<td>Software</td>
<td>Includes Software and System Software and excludes e-commerce</td>
</tr>
<tr>
<td>Telecommunication</td>
<td>Includes Integrated Telecommunication Services, Wireless Telecommunication Services, Communications Equipment, Alternative Carriers, Networking equipment</td>
</tr>
</tbody>
</table>

**Note:** 1. All market sizes in US$. 2. Years indicate CY unless specified otherwise.
## Table Of Contents

1. ACCELERATING GLOBAL ER&D INTENSITY  
   01

2. SOURCING OPPORTUNITY FOR ER&D SERVICES  
   21

3. THE INDIA ADVANTAGE  
   29

4. GROWTH IMPERATIVES FOR INDIA  
   48

5. APPENDIX: MEGA TRENDS DEEP DIVE  
   57

6. APPENDIX: SECTOR DEEP DIVES AND CASE STUDIES  
   98
Accelerating Global ER&D Intensity
Globally, ER&D spending has accelerated post-pandemic and has witnessed a Business ER&D spend CAGR of 7-8% (2020 to 2023)

THE GROWTH OF GLOBAL ER&D UNTIL 2023 CAN BE ATTRIBUTED TO...

- Renewed interest in ER&D post pandemic (including Capex growth)
- Recovering from the pandemic shock which saw reduction in ER&D spends, companies improved ER&D investments to bridge gap between evolving market demand and offerings
- Inflection point for technologies like AI/Metaverse/Social Media
- New technologies drove heightened demand for innovative engineering solutions as companies sought to adapt offerings to consumers who increasingly engaged from home
- Increased demand for digital products and services
- The beginning of digital products and services adoption across various sectors served as a catalyst for ER&D growth

Source: CapitalIQ, BCG ER&D Survey 2023 n=281, Press Search; BCG Analysis

1 Refer glossary for definition

Global Business ER&D Spend\(^1\) ($T)

- 2020: $1.1-$1.5 T
- 2023E: $1.5-$1.8 T
As the world looks forward, **five key mega trends** are expected to shape the future of global business ER&D spend (I/II)

**MEGA TRENDS BEYOND 2023**

1. **DIGITAL ENGINEERING:** INCREASING PROMINENCE

2. **CLIMATE & SUSTAINABILITY AMBITIONS:** KEY DRIVER FOR ER&D SPENDS

3. **AI AUGMENTATION:** GENERATIVE ENGINEERING

4. **SERVICE-ORIENTATION:** SHIFT IN ENGINEERING MODEL

5. **POPULATION & SKILL INVERSION:** SHIFTING SKILLS AND TALENT POOLS

*Source: BCG Analysis*
As the world looks forward, **five key mega trends** are expected to shape the future of global business ER&D spend (II/II)

### MEGA TRENDS BEYOND 2023

|   | DIGITAL ENGINEERING: INCREASING PROMINENCE | CLIMATE & SUSTAINABILITY AMBITIONS KEY DRIVER FOR ER&D SPENDS | AI AUGMENTATION: GENERATIVE ENGINEERING | SERVICE-ORIENTATION: SHIFT IN ENGINEERING MODEL | POPULATION & SKILL INVERSION: SHIFTING SKILLS AND TALENT POOLS |
|---|------------------------------------------|------------------------------------------------------------|----------------------------------------|-------------------------------------------------|------------------------------------------------|---|
| 1 | Integration of digital layers with traditional products or their supplementation is fueling a growing impetus in ER&D. Companies are recognizing the improved outcomes both for themselves and their consumers through this approach. | Global climate targets and evolving regulations driving the agenda for reduction of carbon footprint, building sustainable products and adoption of green energy thus increasing the ER&D intensity. | Generative engineering, powered by AI, automates and optimizes design across industries like automotive, aerospace, and manufacturing – increasing efficiency, and reducing costs. | Innovative trend of product combined with services gaining traction across industries including heavy equipment, automotive and energy sectors resulting in a new ER&D approach focused on building a whole product. | Ageing population and skills gap in several developed economies are reshaping the ER&D spend patterns and intensity. |
Further, specific sectoral developments are expected to drive significant increase in the global business ER&D¹ intensity², taking the spending to $3.3T+ by 2030, from current levels of $1.8T.

### Sectoral developments driving increase in Business ER&D spend

<table>
<thead>
<tr>
<th>Aerospace &amp; Defence</th>
<th>Automotive</th>
<th>Consumer Electronics</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Shifting to more fuel-efficient aircrafts</td>
<td>• Adopting electric powertrains</td>
<td>• Quantum Computing leading to faster market launch</td>
</tr>
<tr>
<td>• Tackling concerns of cybersecurity &amp; increased use of automation</td>
<td>• Transforming automotive value chains with increasing role of software</td>
<td>• Foldable &amp; Flexible Display tech</td>
</tr>
<tr>
<td>• Leveraging additive manufacturing (e.g., 3D printing)</td>
<td>• Connected cars, in-car technologies and Autonomous driving</td>
<td>• Connectivity: Smarter Devices &amp; Homes</td>
</tr>
<tr>
<td>• Urban air mobility</td>
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<td>• Sustainable Electronics</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Energy, Utilities and Oil &amp; Gas</th>
<th>Healthcare &amp; Medical Devices</th>
<th>Industrials including Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The net-zero transition with low-emission technology</td>
<td>• Real-world data &amp; AI-enabled treatment and discovery</td>
<td>• Automation &amp; Robotics</td>
</tr>
<tr>
<td>• Enhancing efficiency through digitization</td>
<td>• Rise of precision medicine and robotic aid</td>
<td>• Platformization</td>
</tr>
<tr>
<td></td>
<td>• Consumer-driven digital health (wearables etc.)</td>
<td>• Data in Industrials</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Semiconductors</th>
<th>Software</th>
<th>Telecommunication</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Innovation in Advanced Packaging &amp; Chip stacking</td>
<td>• Platform to super platforms</td>
<td>• Achieving Hyperconnectivity</td>
</tr>
<tr>
<td>• AI in semiconductor value chain</td>
<td>• Integration of advanced AI/ML into enterprise software suite</td>
<td>• Implementing Open Digital Architecture (ODA) &amp; Virtualization</td>
</tr>
<tr>
<td>• Design customization to meet specific needs of growth frontiers (including AI, xEV, Crypto)</td>
<td>• Integration of advanced AI/ML into enterprise software suite</td>
<td>• Evolving into a “Telco to Techco” Operating Model</td>
</tr>
<tr>
<td></td>
<td>• Continued focus on cybersecurity</td>
<td>• Pervasive 5G &amp; 6G development</td>
</tr>
</tbody>
</table>

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1. Refer Glossary for the description of Global Business ER&D
2. ER&D intensity refers to % of revenue spend on ER&D by firms

Source: CapitalIQ, BCG ER&D Survey 2023 n=281, BCG Analysis
Global Business ER&D spend is expected to grow at an 8-9% CAGR from 2023-2030, up from 7-8% between 2020-2023; thus, signaling increasing ER&D Intensity across sectors.
Even in 2024, amid the dynamic macroeconomic environment, ER&D spending is anticipated to demonstrate resilience across sectors

Analysts are indicating uncertainties in 2024 global economy as they downgrade Global GDP growth forecasts...

**Global GDP Forecasts**

- Amid uncertainties, 2024 Global GDP growth projections have experienced downward revisions in analyst forecasts.
- However, the impact is expected to be short lived, and World Bank predicts a recovery in 2025, with global GDP growth rate pegged at 3.2%.

Despite uncertainties, at least %70+ industry leaders across sectors want to either increase or maintain their ER&D spend in 2024.

- Fastest growing sectors of Software & Telecommunications are resilient to economic downturn & have ~90% of industry leaders surveyed want to maintain or increase ER&D spends.
- COVID-19 pandemic has increased focus on Healthcare & Medical Devices ER&D, with ~100% industry leaders in Healthcare and Medical Devices wanting to increase or maintain their ER&D spend (as a % of revenue).

Automotive, Software and Healthcare & Medical Devices are expected to be top three ER&D spend contributors in 2030

<table>
<thead>
<tr>
<th>Global Business ER&amp;D Spend by Sector ($T)</th>
<th>2023E ($B)</th>
<th>2030F ($B)</th>
<th>CAGR% (2023-2030)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace &amp; Defence</td>
<td>$50-$70 B</td>
<td>$90-$120 B</td>
<td>7-8%</td>
</tr>
<tr>
<td>Automotive</td>
<td>$250-$300 B</td>
<td>$460-$540 B</td>
<td>8-9%</td>
</tr>
<tr>
<td>Consumer Electronics</td>
<td>$150-$230 B</td>
<td>$250-$400 B</td>
<td>7-8%</td>
</tr>
<tr>
<td>Energy, Utilities and Oil &amp; Gas</td>
<td>$110-$140 B</td>
<td>$175-$220 B</td>
<td>7-8%</td>
</tr>
<tr>
<td>Healthcare and Medical Devices</td>
<td>$290-$380 B</td>
<td>$460-$620 B</td>
<td>6-7%</td>
</tr>
<tr>
<td>Industrial including Construction</td>
<td>$140-$160 B</td>
<td>$250-$280 B</td>
<td>8-9%</td>
</tr>
<tr>
<td>Semiconductor</td>
<td>$115-$150 B</td>
<td>$220-$290 B</td>
<td>9-10%</td>
</tr>
<tr>
<td>Software</td>
<td>$160-$220 B</td>
<td>$370-$500 B</td>
<td>12-13%</td>
</tr>
<tr>
<td>Telecommunication</td>
<td>$60-$70 B</td>
<td>$130-$160 B</td>
<td>10-11%</td>
</tr>
<tr>
<td>Others1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

THREE SECTORS EXPECTED TO CONTRIBUTE TO ~50% OF TOTAL GLOBAL BUSINESS ER&D SPEND IN 2030

Automotive
Focus on innovation in xEV, ADAS, in-car entertainment experience, etc.

Software
Driving digitization across sectors and large tech innovations through Generative AI, etc.

Healthcare & Medical Devices
Large R&D investments in pharmaceutical and MedTech innovations

1. Refer glossary for description, share of Others considered as 5% of total; % here indicates sector’s share of global business ER&D spend

Source: CapitalIQ, BCG ER&D Survey 2023 n=281, BCG Analysis
Software, telecom, semiconductors and auto¹ sectors are expected to see high growth rates due to increasing demand & investments to maintain competitive R&D momentum

1. Primarily driven by new breakthroughs, competition from new entrants and incumbents 2. Influenced by TSPs; 3. System on Chip;  

**SOFTWARE**
- Driven by enterprise demands, companies adapting faster product and update releases cycles driving ER&D. Achieving rapid iteration of large-scale complex software has become a necessity in this context
- Detailed engineering work required for integration and end-to-end testing of distributed services driving the demand for development and testing services

**TELECOMMUNICATION**
- Growth prospects of the Telecom sector can be attributed to a blend of factors, including a lower base spend and rollout of 5G and associated applications
- Sector set for expansion as it serves as the fundamental digital infrastructure supporting future applications such as IIoT, Connected Vehicles etc. requiring innovation and investment in network coverage, load management, security, edge computing and resilient connectivity

**SEMICONDUCTOR**
- Growth in Semiconductor demand from sectors including Auto, Telecom and Technology giving rise to application specific innovations and SoC³ developments
- Govt. incentives driving larger private sector investments into R&D (Example: In the US for every $1 federal government investment, private sector adds $20+ investment)

**CAGR % (2023-2030)**

12–13%

10–11%

9–10%

Source: Press search, Alibaba Group, Semiconductor Industry Association; BCG Analysis
Sector wise ER&D Spend Priorities | Deep dive
Aerospace & Defence: ER&D spend expected to reach $90-120B by 2030 growing at ~7-8% CAGR with high focus on additive manufacturing & tech in defence.

**Sector’s ER&D Spend Expected to Reach $90-120B by 2030...**

- 2023E: $50B - $70B
- 2030F: $90B - $120B

**...With Additive Manufacturing & Cyber Security as Key Focus Areas in the Sector...**

- Additive Manufacturing in Components: 60%
- Cybersecurity for Aerospace & Defense: 50%
- AI for Mission Planning & Decision Making: 40%
- Sustainable Aviation & Electric Propulsion: 40%
- Hypersonic Flight & Space Tourism: 35%
- Urban Air Mobility & Flying Taxis: 30%
- Swarming Drones & Autonomous Vehicles: 25%
- Space Debris Removal & Cleanup Initiatives: 10%
- Advanced Satellite Comm & Data Sharing: 10%
- Quantum Key Distribution for Secure Comms: 0%

% of sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years

**...Accompanied by Share of Digital Engineering Reaching ~50%**

2023E: 40%
2030F: 48%

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Automotive: ER&D spend expected to reach $460-540B by 2030 driven by xEV, connected mobility and vehicle software priorities

Automotive Business ER&D Spend expected to inch towards $460-540B by 2030 growing at 8-9% CAGR...

...with electrification, connected vehicles & software as top 3 ER&D priorities for the sector...

% of sector’s ER&D spend on digital engineering increasing by 22pp

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Consumer Electronics: ER&D spend expected to reach $250-400B by 2030 owing to impact of innovations in computing, display technologies and AI

CONSUMER ELECTRONICS ER&D SPEND EXPECTED TO REACH ~$250-400B BY 2030 GROWING AT ~7-8% CAGR...

...WITH QUANTUM, FLEXIBLE DISPLAY & AI AS TOP 3 ER&D PRIORITIES OF THE SECTOR...

% of sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years

CONSUMER ELECTRONICS ER&D SPEND EXPECTED TO REACH ~$250-400B BY 2030 GROWING AT ~7-8% CAGR...

...ACCOMPANIED BY SECTOR’S DIGITAL ENGINEERING AS A % OF ER&D SPEND REMAINING HIGH

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Energy, Utilities and Oil & Gas: Increased focus on green technologies & digital expected to take sector’s business ER&D spend towards $175-220B by 2030

**ENERGY, UTILITIES AND O&G ER&D SPENDS EXPECTED TO REACH $175-220B+ BY 2030...**

![Chart showing sector's business ER&D spend ($B)](chart1.png)

**...WITH DECARBONIZATION, ENERGY-EFFICIENCY & RENEWABLE ENERGY AND DIGITIZATION AS TOP ER&D PRIORITIES...**

![Chart showing top ER&D priorities](chart2.png)

**...WITH SHARE OF DIGITAL ENGINEERING IN ER&D INCREASING BY 22PP**

![Chart showing % of sector's ER&D spend on digital engineering](chart3.png)

---

Multiple choices permitted per respondent. % shows the percentage of experts within a class that determined the choice as a future challenge.

*Source: CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis*
Healthcare & Medical Devices: ER&D spends expected to remain high in healthcare & medical devices making it the highest ER&D spender across sectors.

By 2030, sector expected to lead ER&D spending, inching towards $460-620B...

...with Telemedicine, AI/ML in diagnostics, robotics & personalized therapies as key focus areas...

...accompanied by digital engineering share of ER&D spend reaching 65% by 2030.

Source: BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis.
Industrials including Construction: ER&D spend driven by focus on advances in data backed ops, improving efficiency and quality of output through digital

**INDUSTRIAL ER&D SPEND EXPECTED TO REACH $250B-$280B BY 2030 GROWING AT ~8-9% CAGR**

- **2023**: $140B-$160B
- **2030**: $250B-$280B

**...WITH SUSTAINABILITY, AI-ENHANCED ANALYTICS & AUTOMATION AS TOP 3 ER&D SPENDS...**

- Renewable Energy Integration: 60%
- AI-Enhanced Industrial Analytics: 50%
- Predictive Maintenance for Heavy Machinery: 40%
- Robotics & Automation in Manufacturing: 40%
- Smart Factories & Digital Twins: 35%
- Industrial IoT & Industry 4.0 Transformations: 30%
- AR in Maintenance & Training: 25%
- Blockchain for Supply Chain Traceability: 10%
- Sustainable Building Materials & Construction: 10%
- Circular Economy in Industrial Operations: 0%

**% sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years**

1. Does not include major Chinese companies. Multiple choices permitted per respondent. % shows the percentage of experts within a class that determined the choice as a future challenge. **Source**: BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis

**...ACCOMPANIED BY INCREASING SPEND ON DIGITAL ENGINEERING BY 21PP**

- **2023**: 32%
- **2030**: 53%

**Sector’s Business ER&D Spend ($B)**

$140B-$160B

BCG-Nasscom ER&D Report 2023
Semiconductors: ER&D spend expected to reach $220-290B with focus on areas of packaging and new application specific developments

**SEMICONDUCTORS ER&D SPEND EXPECTED TO REACH $220-290B BY 2030 GROWING AT 9-10% CAGR...**

- 2023E: $115B-$150B
- 2030F: $220B - $290B

**...WITH PACKAGING, ENERGY-EFFICIENCY & QUANTUM COMPUTING AS TOP 3 ER&D PRIORITIES...**

- Advanced Packaging and Chip Stacking: 67%
- Energy-Efficient and Low-Power Designs: 52%
- Semiconductors in Quantum Computing: 52%
- AI-led Innovation: 43%
- Growth of IoT and Edge Devices: 29%
- Heterogeneous Integration of Chips: 24%
- Silicon Photonics for Faster Data Transfer: 14%
- Environmental Sustainability in Manufacturing: 10%
- Neuromorphic Computing & Brain-Inspired Chips: 5%
- R&D in Memory & Storage Technologies: 5%

% sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years

**...ACCOMPANIED BY AN INCREASE IN SHARE OF DIGITAL ENGINEERING AS PART OF ER&D SPEND BY 18PP**

- 2023E: 49%
- 2030F: 67%

Source: BCG ER&D Survey 2023 n=281, Press Search, BCG Analysis
Software: Continuous innovation in software space will leverage new AI breakthroughs; Focus on cloud and cyber security expected to take ER&D spends to $370-500B by 2030

SOFTWARE ER&D SPEND EXPECTED TO REACH $370-500B+ BY 2030 GROWING AT ~12-13% CAGR...

...WITH AI-DRIVEN PERSONALIZATION & CLOUD APPLICATIONS AS TOP TWO PRIORITY AREAS

<table>
<thead>
<tr>
<th>Topic</th>
<th>% of sector respondents who selected the topic as one of top 3 ER&amp;D priority in coming 5-10 years</th>
</tr>
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<tbody>
<tr>
<td>AI-Driven Personalization &amp; Recommendations</td>
<td>78</td>
</tr>
<tr>
<td>Cloud-Native Applications &amp; Microservices</td>
<td>50</td>
</tr>
<tr>
<td>Cybersecurity Solutions &amp; Threat Detection</td>
<td>44</td>
</tr>
<tr>
<td>Integration of AI &amp; Blockchain</td>
<td>38</td>
</tr>
<tr>
<td>Edge Computing &amp; Decentralized Internet</td>
<td>21</td>
</tr>
<tr>
<td>Privacy-Focused Technologies &amp; Data Protection</td>
<td>19</td>
</tr>
<tr>
<td>Voice Commerce &amp; Voice-Activated Devices</td>
<td>12</td>
</tr>
<tr>
<td>Human-Centered Design &amp; Inclusive Tech</td>
<td>10</td>
</tr>
<tr>
<td>Quantum Computing &amp; Cryptography</td>
<td>10</td>
</tr>
<tr>
<td>Sustainable Tech Initiatives</td>
<td>9</td>
</tr>
</tbody>
</table>

Source: BCG ER&D Survey 2023 n=281, Press Search, BCG Analysis
Telecommunication: ER&D spend expected to grow at 10-11% CAGR to reach $130-160B by 2030, maintaining the high share of digital engineering in spends.

Semiconductors ER&D spend expected to reach $220-290B by 2030 growing at ~10-11% CAGR...

...with edge, cloud, SDN, 5G & 6G as top ER&D priorities...

...accompanied by an increase in sector's digital engineering spend as share of ER&D spend.

Not surprisingly, digital engineering is the driving force behind this spend acceleration; expected to contribute 65% of spend\(^1\) in 2030 vs ~45% in 2023

AUTOMOTIVE, ENERGY, UTILITIES, OIL & GAS AND INDUSTRIALS EXPECTED TO SEE LARGEST JUMP IN DIGITAL ENGINEERING AS A % OF GLOBAL BUSINESS ER&D SPEND BETWEEN 2023 & 2030:

Automotive: Most innovations are in software; xEV, ADAS, infotainment systems, connected cars, etc. are driving sector’s spend on digital engineering.

Energy, Utilities, Oil & Gas: Smart grid technology, predictive maintenance of O&G plants, digital simulations, etc.

Industrials: Optimized processes with higher output is driving sector’s spend on digital; e.g., AI-driven analytics, digital twin technology for simulations, predictive maintenance, etc.

Healthcare & Medical Devices has one of the highest contribution to the total spend on digital engineering due to increasing focus on telemedicine, digital in research, wearable devices, remote monitoring, etc.

\(^1\) Spend on digital engineering as a % of Global Business ER&D spend

Source: CapitalIQ, BCG ER&D Survey 2023 n=281, BCG Analysis
Sourcing Opportunity for ER&D Services
Increasing Business ER&D spend is witnessed across regions, and highlights six non-US, non-China countries/sub-regions which are collectively spending $450-600B in 2023.

**GLOBAL BUSINESS ER&D SPEND BY MARKET IN 2023E: $1.8T**

**AMERICAS**
- 37% of total global business ER&D in the region

**EMEA**
- 24% of total global business ER&D in the region

**APAC**
- 39% of total global business ER&D in the region

ER&D spend by firms headquartered in the region in 2023E ($B):
- **$480-645B**
- **$10-15B**
- **$5-10B**
- **$500-600B**
- **$320-430B**
- **$10-20B**
- **$100-130B**
- **$30-55B**
- **$120-145B**
- **$40-50B**
- **$30-40B**

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; BCG Analysis

BCG-Nasscom ER&D Report 2023
Sourcing decisions across sectors are expected to be shaped by 3 factors: Evolving Nature of ER&D, the Chase for Talent and Cost Dynamics.

**Evolving Nature of ER&D**

ER&D has undergone a transformative journey in recent years, with a continued shift from asset-intensive practices to asset-light models. This shift is breaking down traditional boundaries in ER&D teaming models and allowing organizations to Source specific capabilities from non-HQ teams.

**Chasing the Talent**

The demand for multi-disciplinary expertise is driving organizations to look for new talent sources. Also, the talent well-versed with Digital in ER&D is being sought after across sectors (e.g., Software developers for the Automotive sector).

**Cost Dynamics**

Cost dynamics will maintain their role in shaping the sourcing decisions. The ongoing pursuit of cost-efficiency will continue to guide organizations to invest more in scaling up their global ER&D teams (through GCCs) and also drive deeper partnerships with ESPs.

**Sectors most likely to benefit:**

- Aerospace & Defence
- Energy, Utilities and Oil & Gas
- Industrial including Construction
- Software
- Telecommunication
- Automotive
- Semiconductor
- Healthcare & Medical Devices
- Consumer Electronics

---

1. Sourcing %: % of ER&D Spend that is spend on non-HQ teams. This includes spend with GCCs as well as ESPs.

Source: BCG ER&D Survey 2023 n=281, BCG Analysis
Besides cost & talent access, agility & scalability, market expansion, evolving manufacturing footprint, and partnerships...

<table>
<thead>
<tr>
<th>Sector</th>
<th>Cost Optimization</th>
<th>Access To Talent</th>
<th>Time Zone Coverage</th>
<th>Market Expansion</th>
<th>Technological Ecosystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace &amp; Defence</td>
<td>78%</td>
<td>44%</td>
<td>0%</td>
<td>44%</td>
<td>0%</td>
</tr>
<tr>
<td>Automotive</td>
<td>62%</td>
<td>52%</td>
<td>10%</td>
<td>29%</td>
<td>19%</td>
</tr>
<tr>
<td>Consumer Electronics</td>
<td>75%</td>
<td>50%</td>
<td>50%</td>
<td>0%</td>
<td>50%</td>
</tr>
<tr>
<td>Energy, Utilities and Oil &amp; Gas</td>
<td>70%</td>
<td>30%</td>
<td>20%</td>
<td>10%</td>
<td>40%</td>
</tr>
<tr>
<td>Healthcare &amp; Medical Devices</td>
<td>64%</td>
<td>55%</td>
<td>18%</td>
<td>27%</td>
<td>27%</td>
</tr>
<tr>
<td>Industrial including Construction</td>
<td>79%</td>
<td>79%</td>
<td>14%</td>
<td>29%</td>
<td>7%</td>
</tr>
<tr>
<td>Semiconductors</td>
<td>80%</td>
<td>50%</td>
<td>10%</td>
<td>10%</td>
<td>60%</td>
</tr>
<tr>
<td>Software</td>
<td>84%</td>
<td>64%</td>
<td>20%</td>
<td>20%</td>
<td>24%</td>
</tr>
<tr>
<td>Telecommunication</td>
<td>63%</td>
<td>38%</td>
<td>0%</td>
<td>13%</td>
<td>38%</td>
</tr>
</tbody>
</table>

Note: Commentary in next page 1. Sourcing refers to ER&D spend on Global Capability Centers (GCC) and Outsourced Engineering Services (ESP) 2. Each cell refers to % of respondents from the corresponding sector who have ranked the reasons in top 3 selection criteria who said that they will either maintain or increase their ER&D Sourcing (Business ER&D spend on GCCs or ESPs)

Source: BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
...are vital factors for sourcing across industries

<table>
<thead>
<tr>
<th>Trend #1: Cost Optimization &amp; Access to Talent</th>
<th>Trend #2: Market Expansion</th>
<th>Trend #3: Technological Ecosystem</th>
<th>Trend #4: Agility &amp; Scalability</th>
<th>Trend #5: Strategic Partnerships</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost optimization &amp; access to talent are key reasons for sourcing across sectors as skillset requirements are rapidly changing resulting in demand for talent@scale</td>
<td>Companies in sectors like Aerospace &amp; Defence, industrial, automotive, and healthcare &amp; medical devices are exploring opportunities to establish local presence in specific regions, aiming to design and manufacture products tailored to the needs of those markets based on regulatory standards and consumer preferences</td>
<td>Semiconductor &amp; Consumer Electronics industry’s sourcing is also being influenced by changing manufacturing footprint of these industries and the desire of these two sectors to keep design and manufacturing together</td>
<td>Agility and Scalability is a key priority for all organizations, i.e., ability to scale up easily (easy talent availability, plug-&amp;-play infrastructure set-ups, less paperwork, etc.)</td>
<td>Aerospace &amp; Defence places key emphasis on strategic partnerships for collaboration opportunities &amp; access to key stakeholders (with govt., defence contractors, etc.), technological expertise or capabilities of the sourcing country</td>
</tr>
</tbody>
</table>

| 33% | 56% |
| 33% | 19% |
| 50% | 0%  |
| 70% | 30% |
| 55% | 36% |
| 50% | 29% |
| 50% | 10% |
| 44% | 8%  |
| 38% | 25% |

Relative importance of the criteria for sourcing decisions

Key considerations for sourcing

Source: BCG Analysis
It is estimated that global ER&D Sourcing will increase from ~$280B in 2023 to ~$775B in 2030.

As share of Global ER&D Spends (%)

- 2023E: 15%
- 2030F: 24%
- CAGR% (2023-2030): ~16%

Global ER&D Sourcing by sector ($B)

- $210B - 280B
- $600B - 770B

- Software sector to retain the highest share in the sourcing spends in 2030, while share of total sourcing from Energy, Utilities and Oil & Gas and Industrial sector is set to increase by 200bps by 2030.

Above sectors’ gain in share of sourcing stems from the high 2-digit growth (~20% CAGR) in their respective ER&D Spend Sourcing.

1. Refer glossary for description

Source: BCG ER&D Survey 2023 n=281; BCG Analysis
India continues to be well positioned to grab significant share of the Global ER&D Sourcing; India’s advantage is unique combination of ER&D prowess as a top 5 innovative middle-income powerhouse & ability to provide talent @ scale.
India

- World’s largest population, 1.4B+ population
- 8M people tagged to next-gen skills
- ~39M total students enrolled in tertiary education
- ~34% of Graduates in science and engineering
- ~20% of work in Knowledge-intensive employment sectors

Philippines

- 111M population
- ~3.6M total students enrolled in tertiary education
- ~23% of Graduates in Science and engineering
- ~19% of work in knowledge-intensive employment sectors
- List of ~25 engineering courses feature in the list of priority courses for CHED (Commission for Higher Education) scholarships for promoting STEM uptake

Vietnam

- 98M population
- ~2.7M total students enrolled in tertiary education
- ~22% of Graduates in Science and engineering
- ~11% of work in knowledge-intensive employment sectors
- Promoting Industry-Academia tie-ups to promote ER&D; e.g., large telecom equipment provider has partnered with university to set-up AI lab to include work integrated learning in 5G, AI/ML, AR/VR, etc.

Thailand

- 70M population
- ~2M total students enrolled in tertiary education
- ~28% of Graduates in Science and engineering
- ~15% of work in knowledge-intensive employment sectors
- Thai gov has made attracting tertiary students to STEM and STI disciplines a priority in its HRD strategy through curriculum enhancement, scholarships

Bulgaria

- 6.9M population
- ~0.2M total students enrolled in tertiary education
- ~20% of Graduates in Science and engineering
- ~33.4% of work in knowledge-intensive employment sectors
- Private sector support: awards annual scholarships to engineering students who need financial support to continue their studies

Türkiye

- 85M population
- ~8.3M total students enrolled in tertiary education
- ~23% of Graduates in Science and engineering
- ~15.2% of work in knowledge-intensive employment sectors

Few non-India destinations offer engineering talent at India’s scale

1. AI/ML, Big Data, Digital services, IoT
Source: WIPO Global Innovation Index 2022, UNESCO Institute for Statistics, World Bank; BCG Analysis
The India Advantage
India share in ER&D Sourcing expected to increase from $46B in 2023 to $170B in 2030

**Source:** CapitalIQ, BCG ER&D Survey 2023 n=281; BCG Analysis

**INDIA’S SHARE IN THE GLOBAL BUSINESS ER&D SOURCING ($B)**

- **2023E**
  - $44-45B

- **2023-2030**
  - $85-125B

- **2030F**
  - $130-170B

**India Continues to be a leader in ER&D Sourcing**

- **22%** India’s share of global ER&D sourcing market in 2030
- **17%** In 2023

**Note:**
- BCG-Nasscom ER&D Report 2023
Software, Automotive and Semiconductor sectors are expected to contribute 60%+ of India’s share of ER&D sourcing by 2030.

- **Software** to retain the highest share, followed by Automotive inline with the global sourcing trend.
- **Semiconductor** ER&D sourcing share to see the highest jump (9% to 12%) to become the third highest contributing sector by 2030 driven by the global push to use India as a base for Semiconductor manufacturing and which is further accelerating a consolidated design + manufacturing ecosystem in India.

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; BCG Analysis
India expected to see additional opportunities to grow its penetration...

### RELATIVE SOURCING OPPORTUNITY SIZE FOR INDIA FOR NON-US GEOGRAPHIES (2023E)

<table>
<thead>
<tr>
<th>Sector</th>
<th>APAC</th>
<th>EMEA</th>
<th>Americas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Japan</td>
<td>South Korea</td>
<td>Nordics</td>
</tr>
<tr>
<td>Aerospace &amp; Defence</td>
<td></td>
<td></td>
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<tr>
<td>Automotive</td>
<td></td>
<td></td>
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<tr>
<td>Consumer Electronics</td>
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<tr>
<td>Energy, Utilities and Oil &amp; Gas</td>
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<tr>
<td>Healthcare and Medical Devices</td>
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<tr>
<td>Industrial including Construction</td>
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<tr>
<td>Semiconductor</td>
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<tr>
<td>Software</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telecommunications</td>
<td></td>
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</tbody>
</table>

Note: Digital ER&D offerings recommended for the intersections highlighted; 1. Population in the age group of 15-64 years

Source: BCG ER&D Survey 2023 n=281, UNDP zero migration scenario; BCG Analysis

Est. decline in working age\(^1\) population by 2030 compared to 2023 levels

0.5-1.5% 6-7% 2-3% 1-2% 5-6% 1-2% 2-3% 3-4%
... at the intersection of specific sectors & developed economic regions (excluding US)

<table>
<thead>
<tr>
<th>% Digital Engineering in sector (2023)</th>
<th>% Digital Engineering in sector (2030)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40%</td>
<td>48%</td>
</tr>
<tr>
<td>39%</td>
<td>61%</td>
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<tr>
<td>51%</td>
<td>54%</td>
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<tr>
<td>20%</td>
<td>42%</td>
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<tr>
<td>55%</td>
<td>65%</td>
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<tr>
<td>32%</td>
<td>53%</td>
</tr>
<tr>
<td>49%</td>
<td>67%</td>
</tr>
<tr>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>67%</td>
<td>73%</td>
</tr>
</tbody>
</table>

- **Automotive**: Largest Digital engineering spender, esp. Germany, Japan & South Korea
- **Consumer electronics**: Japan and South Korea provide an opportunity due to their demographic shift
- **Energy, Utilities and Oil & Gas**: Digital transformation across Europe (Switzerland, Netherlands, Italy etc.)
- **Industrial**: Companies in South Korea and Japan similarly offer digitization opportunity
- **Software**: Germany’s thriving software industry offers opportunity for collaboration and innovation
- **Telecom**: Germany provides upcoming opportunity owing to sectoral trends
- **Healthcare & Medical Devices, Aerospace & Defence and Semiconductor**: Europe as a key region for innovation and Engineering partnerships
However, to achieve the expected growth, India needs to focus on two key growth challenges.

**01 Skill Synchronicity**
Focus on identifying ER&D skillsets required for industries, and developing an ecosystem to train people for these skills at scale.

**02 Emerging Geo Contenders**
Countries emerging as contenders, with demographic advantages and skill expertise.

*Source: BCG Analysis*
Countries emerging as contenders, with demographic advantages and skill expertise. Focus on identifying ER&D skillsets required for industries, and developing an ecosystem to train people for these skills. 

Source: BCG Analysis
India has an inherent advantage – **Skillset @ Scale…**

### LARGE TALENT POOL

- **66%**
  - Current working age population

- **~2M**
  - STEM talent pool

- **~7M**
  - Total fresh talent in India (UG+PG)

### PRESENCE OF A RICH AND VIBRANT ECOSYSTEM

- **~50K**
  - Active startups in India

- **~25-27K**
  - Active tech start-ups
  - 3000+ in deep tech (such as AI, IoT, and AR/VR)

- **1100+**
  - Universities

- **135+**
  - Global organization investors collaborating with start-ups

- **32% growth YoY in digital talent**

- **>US$8M**
  - Funding to startups through accelerator programs by GCCs

- **US$39.5BN**
  - PE/VC investments to start-ups in 2020

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**Source:** Nasscom “GCC value proposition” report, Nasscom “GCC India landscape: 2021 & beyond” report, BCG analysis; Rise of deep-tech: India home to 3,000+ AI, Big Data and blockchain start-ups, says Nasscom – BusinessToday; How PE Investing in India Has Evolved | Portfolio for the Future | CAIA; India: number of universities | Statista; India: undergraduate degree completion number | Statista; Nearly 2/3rds of Indians are of working age, between 15 and 59 | India News - Times of India (indiatimes.com); Digital India | IBEF
Across sectors survey respondents have mentioned digital skills as key while also needing specific industry skills exposure.

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>DIGITAL SKILLS</th>
<th>INDUSTRY SKILLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace</td>
<td>Data Analytics:</td>
<td>• Mechanical Engineering: Mechanics, Materials, Testing &amp; Prototyping</td>
</tr>
<tr>
<td></td>
<td>• AI/ML and digital technologies</td>
<td>• Embedded/Electrical Engineering: Embedded Systems, Verification and Validation</td>
</tr>
<tr>
<td></td>
<td>• Big data and analysis</td>
<td>• Mechanical Engineering: Mechanics, CAD software for 2D/3D modeling, Testing &amp; Prototyping</td>
</tr>
<tr>
<td></td>
<td>• Data analysis using tools like Python, R, or SQL</td>
<td>• Electrical: Electrical circuit design, Microcontroller-based systems</td>
</tr>
<tr>
<td></td>
<td><strong>Software skills:</strong></td>
<td>• Embedded &amp; Electrical Engineering: Microcontrollers and their programming &amp; applications, Electrical circuit theory and basic component</td>
</tr>
<tr>
<td>Automotive</td>
<td>• At least one programming language (Java, C++, Python, etc.)</td>
<td>• Mechanical Engineering: Mechanics, Geophysics</td>
</tr>
<tr>
<td>Consumer Electronics</td>
<td>• Software development methodologies</td>
<td>• Biomedical skills: Biotechnology/Biochemistry, Electric System of the human body</td>
</tr>
<tr>
<td>Energy, Oil &amp; Gas, and Utilities</td>
<td></td>
<td>• Mechanical Engineering: Mechanics, CAD software for basic 2D/3D modeling, Materials</td>
</tr>
<tr>
<td>Healthcare and Medical Devices</td>
<td></td>
<td>• Embedded Engineering: Microcontrollers and their applications; Analog, Digital, and mixed-signal circuit design &amp; VLSI, Electronic Design Automation (EDA) tools</td>
</tr>
<tr>
<td>Industrial incl Construction</td>
<td></td>
<td>• Project Lifecycle Management: Product documentation and data management</td>
</tr>
<tr>
<td>Semiconductor</td>
<td></td>
<td>• Software engineering: Protocols (OAuth etc.), and security testing</td>
</tr>
<tr>
<td>Software</td>
<td></td>
<td>• Embedded &amp; Electrical Engineering: Microcontrollers and their applications, Technologies such as DWDM, CWDM, SONET, OTN, Ethernet, IP, CMPLS, 5G (incl. ORAN)</td>
</tr>
<tr>
<td>Telecommunication</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: BCG ER&D Survey 2023 n=281, BCG Analysis
Meet Nitin!

Nitin is a Senior Engineer with a leading Automotive ER&D player in Bangalore, working with them since 2015.

He is a B.Tech. in Mechanical Engineering from NIT. As the automotive industry went through the digitization wave with his firm focusing on ADAS, etc., he upskilled himself with a certification course in “Introduction to Internet of Things (IoT) and Connected Cars” from NASSCOM’s futureskills platform. As he was also promoted to Team Manager, he took-up internal trainings in data analytics, and AI to hone his functional skills.

He is looking to hire Automotive ER&D engineering with focus on AI applications in his team to Level 4 ADAS for his company.

Source: BCG ER&D Survey 2023 n=281; BCG Analysis
Meet Maria!

Maria, a Software Engineer employed by an ESP, has been collaborating with an Oil & Gas company based in Mumbai since 2021.

She is a B.Tech. in Computer Engineering from a leading private engineering college in India. She had a month-long onboarding process to help learn about O&G value chain, plant operations, analytics & coding for digital twin, etc. Her job includes developing, updating and maintaining digital twin of the plant along with her team to simulate development, operations, etc.

As the digital wave permeates traditional industries like Oil & Gas, companies like hers are increasingly seeking computer science and data science graduates with domain expertise for recruitment.

Source: BCG ER&D Survey 2023 n=281; BCG Analysis

...even in traditionally conservative sectors like Oil & Gas.
However, it is important to ensure that talent supply meets the demand from the industry.

**INDIAN ACADEMIA SHOULD SEEK BROADER COLLABORATIONS WITH THE PRIVATE SECTOR TO BETTER UNDERSTAND MARKET DEMANDS, DEVELOP CURRICULA TAILORED TO THE NEEDS OF ER&D**

Organizations have established alliances with academic institutions on specific initiatives, including faculty upskilling, student internships, curriculum revision workshops, and research incubation.

**Example**

- Emphasis on internships to foster practical skill development within academic programs, resulting in a robust talent pipeline for the industry. Additionally, harnessing events like hackathons for rapid solution development to achieve similar outcomes as internships.
- Conducting curriculum design workshops from industry for subjects requiring continuous updates and enhancements.
- Promoting shared investment and collaboration in research and development infrastructure between industry and academia.

These sample collaborative initiatives aim to deliver sustainable benefits for skill enhancement among India’s ER&D workforce, amplifying the collective potential of academic and industrial partnerships.

**INDIA’S SKILLSET IN SECTORS WHERE IT REMAINS DOMINANT SUCH AS SOFTWARE SHOULD REMAIN COMPETITIVE**

- Skillsets of ER&D talent should remain competitive and adaptable to the changing requirements for sectors where it holds dominance (Software) and those expected to experience a surge in digitalization (Automotive, Industrial etc.)

Source: Press Search; BCG Analysis
Countries emerging as contenders,
with demographic advantages and skill expertise

Focus on identifying ER&D skillsets required for industries, and developing an ecosystem to train people for these skills at scale
Organizations are actively considering additional sector-specific sourcing locations.

**CHART:** PREFERRED ALTERNATIVE LOCATIONS TO INDIA FOR CURRENT AND FUTURE ER&D CENTERS BY SECTOR

**Source:** BCG ER&D Survey 2023 n=281; BCG Analysis

BCG-Nasscom ER&D Report 2023
India’s share of sourcing market faces competition from nearshoring preference and presence of attractive alternatives backed by their respective investment policies

Nearshoring
Poland, Bulgaria & Mexico identified as preferred future locations across most sectors

POLAND
- Poland boasts a significant proportion of individuals aged 25–34 holding masters and advanced degrees, with a rate of 43%, surpassing both the EU average and several notable countries, including Germany (35%), Italy (29%), Hungary (31%), Bulgaria, and the Czech Republic (33%)
- Poland’s student population exceeds 14 million, surpassing the combined total of students in all other Central and Eastern European countries
- However, average salary in Poland remains at 30% of Germany’s and 35% of France’s average salaries

BULGARIA
- Country evolving from a cost-effective near-shoring location, to a well-recognized European digital hub

MEXICO
- In addition to manufacturing capability, many US companies are considering Mexico or Central America as future ER&D Centres

Source: BCG ER&D Survey 2023 n=281, Press Search; BCG Analysis
ER&D location strategy influenced by government policies; Sectoral policies attracting investments through ecosystem development and financial incentives push

National R&D policies & initiatives, in addition to spillover effect of manufacturing policies attracting investments to new destinations

**THAILAND**
- Thailand Science Park (TSP) was set up with a mission to promote innovation development and R&D activities in private sector
- TSP builds ecosystem to promote and support R&D linkage between government & private sector and stimulate creation of new technology businesses
- National Science and Technology Development Agency (NSTDA) and corporates are closely located in the park, giving corporates access to highly-skilled personnel

**MALAYSIA**
- Malaysian leaders, including PM, have reinforced Malaysia as a regional hub for aerospace & maritime industries in an international exhibition1 held in the country
- National Energy Policy 2022-2040 launched; focus on developing and supporting private sector contribution in this space, esp. towards renewable energy, green tech, etc.

**COUNTRY PREFERENCES BASED ON IP AND SECURITY CONSIDERATIONS**
- Sectors such as Aerospace (with close ties to Defence ER&D), Consumer Electronics and Semiconductor which are of significant national security interest are expected to show bias towards few destinations over others

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1. Langkawi International Maritime and Aerospace (Lima’23) exhibition; **Source**: BCG ER&D Survey 2023 n=281, Press Search, BCG Analysis

BCG-Nasscom ER&D Report 2023
Select examples of sectoral ER&D location preferences (I/III)

**AEROSPACE & DEFENCE**
- USA: R&D centers present in regions with robust Aerospace & Defence industry, driven by talent and local market demand; e.g. A Non-US player established an ER&D center in the US to deliver innovative and cost-effective aerospace components to US and global market.
- Niche talent requirement & partnerships – in fact, firms in our study strongly agree that “Technical industry expertise” is an important factor in choosing the ER&D location; e.g. Companies from large aerospace & defence markets from Europe considering setting up centers in USA.
- South Korea: Large US-based aerospace & defence player set up R&D center in South Korea to collaborate on tech development on advanced production systems, urban air mobility, aerospace semiconductors.

**AUTOMOTIVE**
- Thailand: Present across similar cost-effective R&D geographies.
- Colombia: Presence of Automotive manufacturing in the country or in vicinity highly correlates with ER&D location preference.
- Germany: Green-tech (EV) agenda encouraging innovation, resulting in ER&D centers evolving in developed economies where broader consumer uptake (consumer adoption of xEV) is also driving innovation and availability of talent.
- Hungary: European cost effective centres are also evolving, focusing on AV and EV; examples of firms especially focusing on sensor tech; provides incentives to attract R&D investments.

**CONSUMER ELECTRONICS**
- Asia: Asia continues to be a key ER&D location for CE firms with few regional shifts in recent times:
  - Regulations set forth by Government: Japanese Govt. export restrictions on critical semiconductor equipment has caused CE industry to be wary of ripple effect on adjacent industries.
  - IP concerns: Challenges with IP protection as some countries mandate disclosure of technical details.
- Finland: Talent with advanced skills related to sensor and measurement technology, microelectronics, integrated systems and printed electronics.

Source: BCG ER&D Survey 2023 n=281, Press Search; BCG Analysis.
Select examples of sectoral ER&D location preferences (II/III)

**ENERGY, UTILITIES AND OIL & GAS**
- **Germany.** As the world moves towards renewables, North American companies are looking at European counterparts for renewable tech. Example: Germany has achieved close to 55% RE contribution in its Electricity mix.
- **Brazil and Malaysia.** Traditional O&G ER&D centres see diversification into green tech and renewables ER&D.
- **Other Asian hubs.** Technology seen as key driver for safety in O&G operations, benefiting Asian tech hubs.
- **Others.** R&D leaders such as Singapore offer new solutions in offshore O&G tech (e.g. Submersible Crane).

**HEALTHCARE AND MEDICAL DEVICES**
- **Hungary.** Leading hub for healthcare R&D given biotechnology is one of the top 5 priority sectors with start-ups and subsidies, and tax credits from govt which encourages R&D investment.
  » In the past 10 years, # of people working in pharma sector has increased by 1.5X in Hungary.
  » The Hungarian Government provides cash subsidies for R&D activities based on individual government decisions throughout Hungary.
  » A new R&D Facility in Hungary will Double Annual Testing Capability for pharma.

**INDUSTRIAL INCLUDING CONSTRUCTION**
- **Bulgaria.** Apart from Hungary & Poland, Bulgaria is emerging as a popular sourcing destination; country evolves from a cost-effective nearshoring location, to a well-recognized European digital hub.
  » Operations of Bulgarian tech companies have moved higher up the value chain from support and services to product creation, innovation, research and development.

*Source: BCG ER&D Survey 2023 n=281, Press Search; BCG Analysis*
Select examples of sectoral ER&D location preferences (III/III)

**SEMICONDUCTOR**
- While India is the leading integrated design ER&D hub for the global Semiconductor sector (esp. US) companies, other alternatives are emerging.
- Israel: Availability of Talent driving ER&D sourcing.
- Ireland: Major firms have announced investments into ER&D centres, with country driving innovation in the sector.

**SOFTWARE**
- SEA and Eastern Europe: Due to its asset light nature, companies in the sector are leveraging wide number of geographies for their ER&D centres including regions where market expansion is expected.
- LatAm: Multiple global geographies with stable internet infrastructure and engineering talent are turning into software hubs.

Increased commodization seen in the sector as Engineering development is possible from low cost centres while R&D is concentrated in advanced centres such as US, Germany, India and China.

**TELECOMMUNICATION**
- Europe: Multiple ER&D centres in mainland Europe playing a significant role in the supporting ER&D in the sector.
- Asia: While Hardware innovation takes place close to HQ or through ESPs, software driving the underlying Telecom hardware being developed and maintained by ER&D centres.
- Israel: New innovations such as 6G to be focus area for R&D centres and talent availability to drive ER&D center expansions.

Source: BCG ER&D Survey 2023 n=281, Press Search; BCG Analysis
Growth Imperatives for India
India should focus on growth imperatives in 3 key areas

1. **INFRASTRUCTURE & POLICY SUPPORT**
   - Improving the policy and infrastructure required for ER&D to attract new collaboration opportunities and drive innovation

2. **BRANDING & PROMOTION**
   - Support branding and marketing for ER&D across sourcing markets while promoting a common collaborative agenda from the Indian industry

3. **SKILLING & RESEARCH FOCUS**
   - Industry, Academia and Government to work together to improve talent employability and research quality
Infrastructure Development & Policy Support to drive innovation and improve competitiveness

<table>
<thead>
<tr>
<th>INFRASTRUCTURE-RELATED</th>
<th>POLICY-RELATED</th>
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<tbody>
<tr>
<td>Establish Digital Engineering Innovation Hubs</td>
<td>Incentives for large-scale manufacturing players to move part of ER&amp;D to India</td>
</tr>
<tr>
<td>• Establish Digital Engineering Innovation hubs responsible for collaboration between Academia and Industry to provide innovative digital engineering solutions</td>
<td>• Encourage manufacturing heavy players to <strong>also scale-up</strong> ER&amp;D activities in India</td>
</tr>
<tr>
<td><strong>E.g.</strong> – NASA’s Digital Engineering Design Centre operated by the UTEP (University of Texas at El Paso)</td>
<td>• Encourage sectoral market leaders (across Auto, Telecom, Consumer Electronic, Aerospace) to <strong>shift</strong> larger share of their global design work to India</td>
</tr>
<tr>
<td>Formation of ‘ER&amp;D Industry Labs’</td>
<td>• <strong>Facilitate Funding &amp; partnership opportunities for start-ups:</strong></td>
</tr>
<tr>
<td>• Establish Industry-specific Lab facilities to solve industry-level problems at scale</td>
<td>• Encourage collaboration between ER&amp;D focused start-ups and GCCs, ESPs through structured investment policy and programs</td>
</tr>
<tr>
<td><strong>E.g.</strong> – Labs within entities like ARAI (Automotive Research Authority of India) help standardize testing for vehicles</td>
<td>• <strong>Milestone-based ER&amp;D funding program</strong> for startups</td>
</tr>
<tr>
<td></td>
<td>• <strong>Replicate success of models like</strong> IIT-Madras Research Park which includes sector-specific incubators (e.g., Robotics, EV Powertrain, Battery Tech) for deep-tech start-ups (detailed case study on next page)</td>
</tr>
</tbody>
</table>

Source: Expert Inputs, Press Search; BCG Analysis

**BCG-Nasscom ER&D Report 2023**
IIT-Madras Research Park (IITMRP) | R&D focused innovation and research program

**BACKGROUND**

IIT-Madras has successfully built a knowledge and innovation ecosystem where ideas can not only be generated, but also incubated and scaled.

**PROBLEM STATEMENT**

- Companies looking set up R&D facilities in India often faced several challenges – lack of supporting ecosystem, lack of skilled resources, poor lab and test facilities, etc.
- IIT-Madras also wanted to set up a platform for incubating innovative ideas coming from students.

**DESCRIPTION OF SOLUTION**

- IITMRP was started in 2010
- Today it has 16 Departments, over 600 Faculty, 3,500 Research Scholars, Hitech Laboratories, testing facilities and Innovation Centres
- Centres of Excellence at IITMRP partner with companies/startups for specific research and also share their lab resources with partners and startups

**IMPACT**

- 70+ R&D partners across 17 sectors
- 200+ start-ups incubated across 13 sectors
- 1300+ patents filed

**FOCUSED RESEARCH AREAS FOR IITMRP CLIENTS**

Source: IIT-Madras website; BCG Analysis
Branding & Promotion - India’s ER&D achievements and potential need to be promoted and amplified across the globe

**Initiatives**

<table>
<thead>
<tr>
<th>Description</th>
<th>Source: Expert Inputs, Press Search, Govt. of India, Invest India; BCG Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establish Digital expo to showcase India ER&amp;D</td>
<td>• Launch digital expo to showcase India's ER&amp;D strengths, credentials and investment opportunities to connect international audience with the Indian ER&amp;D community</td>
</tr>
<tr>
<td>Capability Roadshows in key ER&amp;D sourcing markets</td>
<td>• Showcase Indian ER&amp;D story by organizing Capability Roadshows in key ER&amp;D sourcing markets</td>
</tr>
<tr>
<td>Showcase Brand ‘ER&amp;D India’ at global marquee events</td>
<td>• Identify critical sector-specific marquee events to showcase Brand ‘ER&amp;D India’ before high-profile industry leaders and government representatives</td>
</tr>
<tr>
<td>Delegation management for international trade shows</td>
<td>• Actively manage the selection and composition of delegations (comprising of relevant ER&amp;D experts) from various sectors to participate in prominent international ER&amp;D events, such as Trade Expos and ER&amp;D summits to promote India as an ER&amp;D destination</td>
</tr>
<tr>
<td>Amplification through ad agencies/digital marketing firms in key sourcing markets</td>
<td>• Promote brand ‘ER&amp;D India’ through specialized B2B ad agencies/digital marketing agencies in priority markets for ER&amp;D sourcing</td>
</tr>
</tbody>
</table>

**Source:** BCG-Nasscom ER&D Report 2023
The Knowledge Transfer group at CERN has initiated a pilot programme in collaboration with the Israel Innovation Authority.

The purpose of the programme is to explore how cutting-edge Israeli companies and institutes can embrace specific CERN technology and know-how to fuel their innovation and help drive positive impacts for society.

The Israel Innovation Authority funded 4 companies to collaborate with CERN:
- CEVA (neural networks)
- All-In-Image (Machine Learning in Medicine)
- ImmunoBrain Checkpoint (Cell simulation)
- HIL Applied Medical (Proton Therapy solutions)

These companies have partnered with CERN to develop practical use-cases for CERN technologies.

Israel's focus on promoting ER&D expertise in certain sectors led to recognition and collaboration with CERN.

Scientific advances in accelerators, detectors and computing have led to positive impacts on medical and biomedical technologies.

3 out of the 4 programs are related to medical and biomedical applications.

Source: CERN website, BCG Analysis.
Graduate skill deficit and quality of research output requires immediate attention

**Pilot to launch ER&D curriculum in Top 100 engineering colleges**
- Initiate a pilot program introducing an ER&D certification curriculum in addition to degree programs across India’s top 100 engineering colleges
- Program to lead to specialized training and qualification for ER&D skillset; Curriculum for pilot program to be reviewed periodically with industry experts

**Industry-Academia collaboration to be extended to Tier-2 colleges**
- Need to identify research areas, refine curriculum and act as conduit between Industry and Academia to identify next set of ER&D-ready engineers
- Collaboration between Industry and Academia required to move beyond top-tier institutes to improve quality of graduate pool
- This initiative will also aid improvement in research quality and intensity

**Incorporate industry inputs with research priorities of National Research Foundation (NRF)**
- Align industry ER&D inputs with research priorities of national R&D initiatives (like NRF)
- E.g. – Israel’s Research & Development fund offers the largest financial incentive for Israeli corporations’ R&D activity

Source: Expert Inputs, Press Search, Govt. of India, Invest India, Union Budget – Saptarshi Priorities, BCG Analysis

BCG-Nasscom ER&D Report 2023
Taiwan: STEM to STEAM model | Curriculum redesign to increase enrollment in STEM disciplines at secondary school level

BACKGROUND
Taiwan introduced STEAM (science, technology, engineering, arts, and mathematic) to attract more students to STEM at the secondary level education and placed great emphasis on arts and design-related disciplines.

PROBLEM STATEMENT
- Gender disparities in the interest towards STEM disciplines are substantial
- Research from United Nation’s Educational, Scientific, and Cultural Organization (UNESCO) shows that female students represent only 35% of all students enrolled in STEM-related degrees worldwide
- Lack of women participating in STEM would hinder Taiwan’s economic development and reduce the diversity of perspectives and the ability to offer different answers and breadth to new problems

DESCRIPTION OF SOLUTION
- STEAM can be understood as the integration of STEM with arts, such as design, creative thinking, and any interdisciplinary education approach, and emphasizes the synergy of creativity and problem-solving skills
- In order to attract more students to STEM careers, Taiwan changes its curriculum to incorporate STEAM into primary school education

IMPACT
- Eventually, the country’s secondary education system moved to a more gender-equal, dynamic, and interdisciplinary STEAM approach
- As a result of this program, Women’s enrollment and interest in STEM-related disciplines increased

Source: MDPI database; BCG Analysis
Appendix

Mega Trends
Deep dive
5 Mega trends that will affect ER&D

1. **Digital Engineering**: Increasing prominence
2. **Climate & Sustainability Ambitions**: Key driver for ER&D spends
3. **AI Augmentation**: Generative Engineering
4. **Service-Oriented**: Shift in engineering model
5. **Population & Skill Inversion**: Shifting skills and talent pools

*Source: BCG Analysis*
1 DIGITAL ENGINEERING: INCREASING PROMINENCE
ER&D firms are moving from traditional pillars of mechanical, electrical, etc. to now focus on digital engineering (software, data analytics & embedded).

<table>
<thead>
<tr>
<th>% of Global Business ER&amp;D spend on digital engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>45% (2023)</td>
</tr>
<tr>
<td>+20pp</td>
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<tr>
<td>65% (2030)</td>
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</table>

### DEVELOPMENTS IN DIGITAL ENGINEERING...

- Constant innovation leading to more demanding customer expectations
- Increasing reliance on Software and coding - Large quantum of data creation, capture, reporting and dissemination
- Virtual testing (Digital Twin)

### ...LEADING COMPANIES TO PIVOT TO NEW CAPABILITIES

- New product categories to be developed within existing portfolio (e.g., Connected cars, Smart factories)
- Data analytics capabilities to constantly reinvent product categories and launch more personalized products
- Data protection measures to be put in place to ensure data security and compliance
- Reduced costs and lead-time for R&D

Source: BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Digital engineering is transforming ER&D, enhancing efficiency, cost-effectiveness, and the ability to deliver groundbreaking solutions across sectors.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Use cases for Digital Engineering</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace &amp; Defence</td>
<td>• Unmanned aerial systems</td>
<td>• Knowledge of aerodynamics supported with knowledge of ML for inducing autonomy in UAS</td>
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<td></td>
<td>• Development supported by AR/VR simulation</td>
<td>• High proficiency in AR/VR development platforms like Unity</td>
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<tr>
<td>Automotive</td>
<td>• Autonomous vehicles</td>
<td>• Enhanced coding skillsets required for writing code for autonomous vehicles and advanced S/W features</td>
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<td></td>
<td>• Vehicle connectivity/infotainment features</td>
<td>• Expertise in designing and developing circuitry for AV/VR devices and connected electronics along with dev platforms</td>
</tr>
<tr>
<td>Consumer Electronics</td>
<td>• AV/VR enabled entertainment</td>
<td>• Familiarity with different 3D printing technologies like FDM, SLA, SLS, etc.</td>
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<td></td>
<td>• Connected devices</td>
<td>• Familiarity with cloud platforms &amp; understanding of IoT security protocols</td>
</tr>
<tr>
<td>Industrial including Construction</td>
<td>• Additive manufacturing (3D printing)</td>
<td>• Knowledge of software-defined networking (SDN) and network function virtualization (NFV) along with rich coding skillset</td>
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<tr>
<td></td>
<td>• Industrial IoT</td>
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<td></td>
<td>• Digital Twin</td>
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<tr>
<td>Semiconductor</td>
<td>• Automated customer experience (with AI enablement)</td>
<td>• Higher sourcing in sector given Energy is a traditional sector and internal talent is limited</td>
</tr>
<tr>
<td></td>
<td>• Virtualization</td>
<td></td>
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<tr>
<td>Energy</td>
<td>• Smart grid in power &amp; utilities segment</td>
<td></td>
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<tr>
<td></td>
<td>• Digital (AI/ML, etc.) in O&amp;G value chain</td>
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Illustrative not exhaustive

Source: Press Search; BCG Analysis
About the Company
Company: Maruti Suzuki
Megatrend: Digital Engineering

Need of ER&D
- Unavailability of equipment level real-time energy consumption
- Difficulty in wastage identification
- Manual process tedious and time taking

Innovation Brief
Equipment-level energy analytics solution that combines non-invasive & maintenance-free sensors and data-driven energy analytics to enable deeper visibility into production efficiency using site's energy consumption on real-time basis. Urja.io is the co-creator

Description of Solution
- IoT Energy sensors to capture equipment level data
- Non-Intrusive, Plug and Play
- 24x7 Real time data

Impact
- Yearly Cost Savings – Energy savings of INR 2 Crores and Productivity savings of INR 2.5 Crores
- Reduced Downtime of the machine by predictive analytics
Maruti Suzuki | Energy Management IoT solutions
NEED OF ER&D

- A building’s entire lifecycle is estimated to be responsible—both directly and indirectly—for around 40% of global CO2 emissions.
- In addition to the process-related emissions, the carbon generated throughout the building lifecycle is also a large contributor.
- Inefficiencies and poorly managed buildings are leading to wasted energy and higher CO2 emissions, leading to increased financial costs and reduced building occupant satisfaction.

INNOVATION BRIEF

Twinalytics converts physical assets to digital, integrates ecosystems, provides a single-source-of-truth, and delivers a data-driven, human-centric experience.

DESCRIPTION OF SOLUTION

- Twinalytics enables customers to assess business value and sustainability, providing a roadmap to a sustainable future. It includes data and analysis for energy, thermal comfort, solar, daylight, and wind loads.
- Twinalytics combines IoT and BIM for a smart, real-time digital twin that enhances decision-making and evolves dynamically.

IMPACT

- Digital Factory: Real-time insights, enhanced efficiency.
- Carbon Footprint: Energy analysis, AI/ML predictions.
- Human-Centric: Boost workforce productivity, safety, and well-being through thoughtful environmental planning.
- Building LCA: Enables our customers to get certifications like LEED & BREEAM.
HCLTech | Twinalytics

SUSTAINABILITY KPIS TRACKED BY TWINALYTICS

HIGH LEVEL ARCHITECTURE OF TWINALYTICS

REALTIME PERSONA BASED INSIGHTS

DEVELOPED PHYSICS BASED MODELS IN BIM - REVIT

SENSOR INTEGRATION & DATA ENABLEMENT IN 3D SPACE
5 Mega trends that will affect ER&D

1. 

2. CLIMATE & SUSTAINABILITY AMBITIONS KEY DRIVER FOR ER&D SPENDS

3. 

4. 

5. 

Source: BCG Analysis

BCG-Nasscom ER&D Report 2023
Climate & Sustainability ambitions key driver for ER&D spends

COMPANIES HAVE A SIGNIFICANT CLIMATE IMPACT...

Fortune 500 companies are estimated to be responsible for around 27% of global emissions.1

...AND STAKEHOLDERS ARE APPLYING PRESSURE TO ACT...

127 countries now have restrictions on single-use plastic.

62% take sustainability into account in their portfolios.2

2/3 applicants are more willing to apply for and accept jobs from a sustainable company.3

CREATING NEED FOR BOLD TARGETS AND SUPPLY CHAIN TRANSFORMATIONS

A Fifth Of World’s Largest Companies Committed To Net Zero Target

1. Recapture Carbon, as of 2019 2. References personal investors (IBM); 3. IBM, 4. Forbes

Source: BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Several areas of global industry under transition to minimize impact of climate change on economic activity

**CLIMATE CHANGE MITIGATION**
Decarbonisation, abatement of GHG emissions and removal of GHG from the atmosphere

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<tbody>
<tr>
<td>1.1 Renewables tech and services</td>
<td>2.1 Electrified private transport</td>
<td>3.1 Hydrogen</td>
<td>4.1 Building energy efficiency</td>
<td>5.1 Power &amp; heat co-generation</td>
<td>6.1 Carbon capture, utilization or storage (CCUS and DAC)</td>
</tr>
<tr>
<td>1.2 Nuclear power</td>
<td>2.2 Electrified public transport</td>
<td>3.2 Sustainable fuels</td>
<td>4.2 Industrial heat optimization</td>
<td>5.2 Waste-to-energy solutions</td>
<td>6.2 Methane and flare gas capture</td>
</tr>
<tr>
<td>1.3 Utility scale storage</td>
<td>2.3 Electric charging infrastructure</td>
<td>3.3 Biomass as heating fuel</td>
<td>4.3 Motor &amp; machinery efficiency</td>
<td>5.3 Recycling &amp; resource recovery</td>
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<tr>
<td>1.4 Power networks &amp; transmission</td>
<td>2.4 Heat pumps</td>
<td>3.4 Low-carbon building materials</td>
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<tr>
<td>1.5 Distributed energy</td>
<td>2.5 Electric arc furnaces (iron &amp; steel)</td>
<td>3.5 Sustainable packaging</td>
<td></td>
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<tr>
<td></td>
<td>2.6 Marine electrification</td>
<td>3.6 Climate-focused materials mining</td>
<td></td>
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Source: BCG Analysis
### CLIMATE CHANGE ADAPTATION & RESILIENCE

Resilience of key systems and infrastructure against extreme weather scenarios caused by climate change

<table>
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<tbody>
<tr>
<td>7.1 Nature base solutions</td>
<td>8.1 Carbon measurement &amp; accounting</td>
<td>9.1 Agriculture Technology</td>
</tr>
<tr>
<td>7.2 Negative emission technologies</td>
<td>8.2 Leak detection and repair</td>
<td>9.2 Alternative proteins</td>
</tr>
<tr>
<td>7.3 Carbon markets &amp; services</td>
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<tbody>
<tr>
<td>10.1 Infra-structure resilience</td>
<td>11.1 Catas-trophe risk management</td>
<td>12.1 Industrial water treatment and technologies</td>
</tr>
<tr>
<td>10.2 Flood &amp; water mgmt.</td>
<td>11.2 Eco-system conservation &amp; restoration</td>
<td>12.2 Municipal water treatment and technologies</td>
</tr>
<tr>
<td>10.3 Early warning systems</td>
<td></td>
<td>12.3 Water equipment enhancement technology</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.4 Water harvesting and drip irrigation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.5 Other efficient water infrastructure</td>
</tr>
</tbody>
</table>
Three archetypes emerge to address climate & sustainability challenges which will collectively drive ER&D spends aimed at C&S

<table>
<thead>
<tr>
<th>Types of approach</th>
<th>Areas of impact</th>
<th>Impact on ER&amp;D players</th>
</tr>
</thead>
<tbody>
<tr>
<td>GREEN TRANSITION ENABLER</td>
<td>Industries with inherent low carbon footprint and can reduce global emission indirectly (e.g., new teleconferencing software)</td>
<td>• Impact mainly a result of emissions reduced associated with the use of its products</td>
</tr>
<tr>
<td></td>
<td>• Developing products, technologies, and software that directly reduces emissions</td>
<td>• Cross-industry ER&amp;D collaboration</td>
</tr>
<tr>
<td>GREEN TECH PRACTITIONER</td>
<td>Industries with some carbon footprint yet can reduce global emission directly, esp. as part of a green infrastructure (e.g., solar PV manufacturers)</td>
<td>• Impact a mixture of the industry’s GHG emission reduction efforts and the result of emissions reduced associated with the use of its products</td>
</tr>
<tr>
<td></td>
<td>• ER&amp;D for more efficient, durable, and cost-effective RE technologies</td>
<td>• ER&amp;D efforts for seamlessly integrating RE technologies into larger energy systems (grid etc.)</td>
</tr>
<tr>
<td>TRANSITIONING CARBON EMITTER</td>
<td>Industries from emission-intensive sectors with high carbon footprint (e.g., Green innovations in Oil &amp; Gas companies)</td>
<td>• Climate impact results predominantly from its own green transition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ER&amp;D activities to meet evolving regulations and environmental standards</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Green innovations to address new markets and customer segments</td>
</tr>
</tbody>
</table>

**Source:** BCG Analysis

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<tr>
<td>GREEN TECH PRACTITIONER</td>
<td>Automotive</td>
</tr>
<tr>
<td>TRANSITIONING CARBON EMITTER</td>
<td>Energy, Oil &amp; Gas Industrial incl Construction Aerospace &amp; Defence</td>
</tr>
</tbody>
</table>

Source: BCG-Nasscom ER&D Report 2023
**ABOUT THE COMPANY**

**Company:** Baker Hughes  
**Megatrend:** Sustainability

---

**NEED OF ER&D**

- **NOx emission estimation is crucial**
  - to develop combustion system control logic or hardware, to achieve a green, regulatory-compliant gas turbine
- **Emission measurement is often challenging**
  - because sensor purchase, installation and maintenance is costly or unfeasible due to harsh conditions

---

**DESCRIPTION OF SOLUTION**

- **Our solution leverages AI techniques**, in particular a deep learning approach
- **A neural network has been trained**
  - to regress NOx values and some advanced technique has been used to assess regression feature importance. This enables design and control engineers to better understand factors affecting NOx emission levels
- **This approach combines deep learning’s high accuracy and improved reconstruction error**, resulting in over a 5% improvement in estimation accuracy

---

**INNOVATION BRIEF**

A surrogate model for NOx emissions has been built, taking as input sensor measurements describing 100% hydrogen-fueled burners operating conditions

---

**IMPACT**

- **An early pollutants estimation**, starting from combustion chamber operation design, allows to get to a low-emission final product
- **Moreover, it reduces design reworking and testing activity**, thus also reducing the total environmental impact of the product development
Baker Hughes | NOx estimator for a gas turbine

Feature importance ranking

Reconstruction accuracy fulfills customer acceptance criteria
ABOUT THE COMPANY

Company: Infosys  
Megatrend: Sustainability

NEED OF ER&D

- Features like loss analysis, demand forecasting, economic analysis and auto maintenance scheduler are essential features in water management.
- To develop a best-in-class solution for enhanced real time monitoring and analysis of water usage we developed a software concept with advanced analytical capabilities.

DESCRIPTION OF SOLUTION

- Solution interfaces with diverse hardware, collects real-time data, and provides industry-standard KPI dashboards.
- Water loss analysis quantifies campus losses, including leaks, non-revenue water, and etc.
- Water demand forecast with statistical models and alerts, aiding staff with issue resolution and troubleshooting guidance.
- Auto maintenance scheduler tracks and assigns maintenance activities until completion.

INNOVATION BRIEF

This enterprise solution provides a unified view of water usage efficiency across all levels and locations, reducing wastage and aligning with sustainability goals.

IMPACT

- Smart Water Solution monitors continuously, detects and plugs leaks promptly.
- At Infosys, it reduced freshwater consumption by 64%, achieving 100% water recyclability, winning IoT projects and driving sustainability initiatives.
Infosys | Smart Solution for Water

- Third party integration
- Real-time data
- Real time alerts and notifications
- Benchmarking of campuses/buildings
- Achieve Water sustainability goals
- Zero Water Leakage

Infosys Smart Solution for Water

BCG-Nasscom ER&D Report 2023
ABOUT THE COMPANY

Company: KPIT
Megatrend: Automotive

NEED OF ER&D

- The increased demand for energy, coupled with the pressing need to transition to cleaner alternatives, presented an urgent opportunity for us to revolutionize the way energy is generated and utilized within urban spaces.

INNOVATION BRIEF

This project not only addresses the pressing challenges of harnessing and energy consumption, also sets new standards in environmental responsibility and urban design.

DESCRIPTION OF SOLUTION

- We have taken a proactive approach to harnessing renewable energy by transforming our open parking lots into covered parking areas using solar panels. These solar panels generate clean and sustainable energy, provide shelter to 600+ vehicles.

- The Solar Car Park represents a milestone in sustainable innovation, demonstrating our unwavering commitment to environmental stewardship, technological advancement, and societal betterment.

IMPACT

- Total plant capacity: 661.65 Kwp
- Total solar modules: 2005 (330 WP each)
- Annual power generation: 960,000 units
- Annual carbon emission reduction: 800 tonnes
- Annual cost savings: ~INR 3+ Millions
Our commitment to environmental sustainability has enabled us to develop solutions that help Mobility leaders reduce their carbon footprint and lay the foundation for a cleaner, smarter, and safer future. We are consistently enhancing efforts to minimize our impact on the natural environment, increase contributions for community development projects and improve our corporate governance framework.

### Water Conservation
At KPIT, we focus on water conservation and recycling efforts, which include the installation of sewage treatment plants in our facilities.

- 11,975 KL water conserved

### Energy Consumption
At KPIT, we made efforts in reducing energy consumption, generating clean and sustainable energy, contributing to our commitment to encourage environment-friendly practices.

- 2,105 GJ Energy consumed reduced
- 33.74 GJ Energy consumed from Renewable sources

### Waste Management
Recognizing the environmental consequences associated with e-waste, we at KPIT take precise steps to promote its use within underserved communities.

- 4.5 tonnes E-waste collected

**FULFILLING THE PROMISE OF SUSTAINABILITY**
5 Mega trends that will affect ER&D

1

2

3 AI AUGMENTATION: GENERATIVE ENGINEERING

4

5

Source: BCG Analysis
Gen AI will augment, not replace, traditional AI capabilities and make them more accessible.

<table>
<thead>
<tr>
<th>TRADITIONAL AI STRENGTHS</th>
<th>GEN AI STRENGTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sense patterns and trends</td>
<td>Doc/meeting summaries</td>
</tr>
<tr>
<td>Target government investments</td>
<td>Review and draft contracts</td>
</tr>
<tr>
<td>Service segmentation and design</td>
<td>Customer engagement</td>
</tr>
<tr>
<td>Target ‘risk treatment’</td>
<td>Messaging content generation</td>
</tr>
<tr>
<td>Optimise public assets and operations</td>
<td>Code generation</td>
</tr>
<tr>
<td>Anomaly/Fraud detection</td>
<td>Social media monitoring</td>
</tr>
</tbody>
</table>

Source: Press Search; BCG Analysis
With vast and growing number of use cases with many expected to become table-stakes; driving companies to invest in topic’s ER&D

**FOUNDATIONAL GEN AI CAPABILITIES & ENABLERS**
Embedding Gen AI tools in data extraction, aggregation and analytics processes

**NEW PRODUCTS & VALUE PROPOSITION**
New applications and analytics generating insights not possible without Gen AI computing power

**EFFICIENCY & COST LEVERS**
Automation of manual tasks (data cleaning, labelling, tagging, assurance, …)

**DELIVERY & SERVICE EXCELLENCE**
Increased personalization and higher level of service for customers

**TABLE-STAKES USE CASES**
- Lower barrier to adoption
- Essential to keep pace with peers; competitive disadvantage, if not adopted

**ENABLING USE CASES**
- Offer differentiation in current market while technology is still maturing
- Barrier to adoption reduces over time

**GOLDEN USE CASES**
- Unique applications that drive value
- Challenging to develop and adopt
- Users will incorporate into workflows creating barriers to change

Source: Press Search; BCG Analysis
Internal processes across all industries can benefit from generative AI horizontal use cases

<table>
<thead>
<tr>
<th>FUNCTIONS</th>
<th>Marketing</th>
<th>Sales</th>
<th>Logistics and distribution</th>
<th>Customer support</th>
<th>Customer success</th>
<th>Legal</th>
<th>Finance</th>
<th>Human resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENAI USE CASES</td>
<td>Hyper-personalized campaigns</td>
<td>Personalized sale pitch generation</td>
<td>Conversational assistant for logistics coordination</td>
<td>Conversational assistant responding to customer queries</td>
<td>Dashboard and report generation to track key metrics</td>
<td>Legal document review and synthesis to extract key points</td>
<td>Business case draft</td>
<td>Conversational assistant for employee knowledge mgmt.</td>
</tr>
<tr>
<td></td>
<td>White papers, blogs, commercial, and ad writing</td>
<td>Demos tailored to customer environment</td>
<td>Supply chain optimization from demand forecast</td>
<td>Auto-generated user guides &amp; tutorials</td>
<td>Account profile generation to find upsell opportunities</td>
<td>Convert Legalese into plain English</td>
<td>Financial statement and budget draft</td>
<td>Virtual recruiter for sourcing, interviewing, and screening</td>
</tr>
<tr>
<td></td>
<td>Visual marketing material generation</td>
<td>Client outreach email writing</td>
<td>Robot route planning in warehouse</td>
<td>Support swarming w/ recommended resolutions</td>
<td>Customer sentiment and experience mgmt.</td>
<td>Contract draft creation</td>
<td>Sale forecasting using full body of data (e.g., AE sentiment)</td>
<td>Workforce training and job simulation</td>
</tr>
<tr>
<td>POTENTIAL IMPACT</td>
<td>5–10X Faster content gen¹</td>
<td>4X Reply rates²</td>
<td>99% Accuracy in order execution³</td>
<td>42% Outbound calls eliminated⁴</td>
<td>12% Net rev. retention increase⁵</td>
<td>70% Increase in productivity⁶</td>
<td>5X Faster deployment⁷</td>
<td>$1M In savings⁸</td>
</tr>
</tbody>
</table>


Source: Press search; BCG analysis
### Example 1: Sector specific use cases | Semiconductor chip design

<table>
<thead>
<tr>
<th>VALUE CHAIN</th>
<th>RTL generation</th>
<th>Verification</th>
<th>Physical Design</th>
<th>Customer tuned models</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENAI USE CASES</td>
<td>Generate RTL code based on descriptive prompt</td>
<td>Shortlist error causes, conduct root cause analysis, and recommend solutions</td>
<td>Generate first pass physical design with specific optimizations</td>
<td>Enable customers to personalize established models via Gen AI integrations</td>
</tr>
<tr>
<td>(E.g., write an AND gate using IEEE package)</td>
<td>Estimate issue probability Generate synthetic data for simulation &amp; testing</td>
<td>Incorporate historic characterization data into recipe steps</td>
<td>Customers can reuse and modify existing designs more easily</td>
<td></td>
</tr>
<tr>
<td>POTENTIAL IMPACT</td>
<td>Increase R&amp;D engineer productivity and satisfaction</td>
<td>Reduce debugging time and risk of errors</td>
<td>Increase process efficiency and speed to market;</td>
<td>Unlock new design possibilities &amp; increase customer share-of-wallet</td>
</tr>
</tbody>
</table>

Source: Press search; BCG analysis
**Example 2: Sector specific use cases | Biopharma**

<table>
<thead>
<tr>
<th>VALUE CHAIN</th>
<th>Drug Discovery</th>
<th>Drug Development</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENAI USE CASES</td>
<td>Systematic protein and drug molecule generation</td>
<td>Auto-generate clinical reports and other relevant documents</td>
<td>Determine and produce optimal production conditions</td>
</tr>
<tr>
<td>Identify target patients using biological data</td>
<td>Clinical trial design and optimization</td>
<td>Digital twin to simulate production and product testing</td>
<td></td>
</tr>
</tbody>
</table>

**POTENTIAL IMPACT**

- ~1,000x Faster than state-of-the-art computational models¹
- >60% Time-saving for medical writers²

---

¹ MIT research ² ZYLiQ website

**Source:** Press search; BCG analysis

BCG-Nasscom ER&D Report 2023
Samsung | Unlocking secure and fair code generation

### ABOUT THE COMPANY

**Company:** Samsung  
**Megatrend:** GenAI

### NEED OF ER&D

- An Organization with major focus on Research and Development, it is required to secure our code.
- This restricts us from utilizing tools available in the market. Also, they lack domain-specific knowledge, resulting in less relevant suggestions for organization specific needs. And they will not be 100% aligned with our organization’s coding guidelines.

### DESCRIPTION OF SOLUTION

- Our idea is to train the best open source LLM with a domain specific dataset and develop extensions/plugin to connect with the trained model from developer IDEs.
- Thus, developers working on the specific Domain can get code completion suggestions from the model, from the comfort of their IDE without worrying about the privacy and security.
- Trained model will be familiar with the coding guidelines of the organization since it’s trained on in-house datasets.

### INNOVATION BRIEF

An AI based Code generation system that can write code alongside human developers. This in-house system helps to improve development efficiency, reduce errors, and increase the speed of our software development.

### IMPACT

- Our solution **accuracy** is 80% compared to that of Market tools which is only 20%.
- 100% Data Privacy and Security.
- 100% adherence to Organization Coding Guidelines.
- Average 25%~30% increase in Developer productivity.
Samsung | Unlocking secure and fair code generation

S-Coder, an AI based Tool, can be used in the Development Environment by every developers in our organization to improve their productivity in a safe and secure way thereby protecting our company data.

Key Features:
- Natural language comment to code
- Function header to function body completion
- Partial code completion based on previously written lines

Training Methods:
- We have used the below Training methods for Model Training
  - Supervised learning
  - Supervised fine-tuning (SFT)
  - Reinforcement learning with Human feedback (RLHF)

Evaluation Results:
100 Prompts [Android] were taken for evaluating its performance. This is a Human Feedback based evaluation and **Lower Score indicates good recommendation.** (Score goes up, quality of recommendation reduces)
5 Mega trends that will affect ER&D

1
2
3
4 SERVICE-ORIENTATION: SHIFT IN ENGINEERING MODEL
5

Source: BCG Analysis
Ecosystems are forming across industries, creating innovative products and services...

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evolving Customer Demands ...</strong></td>
<td><strong>Are driving new business models...</strong></td>
<td><strong>...to develop new offerings</strong></td>
</tr>
<tr>
<td>• Personalized experience</td>
<td>• Network of partners and contributors</td>
<td>• Connected cars</td>
</tr>
<tr>
<td>• Continuous innovation</td>
<td>• Data-intensive</td>
<td>• Industrial service bundling</td>
</tr>
<tr>
<td>• Seamlessly integrated customer journey</td>
<td>• Flexible and resilient</td>
<td>• Smart factories</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Collaborative supply chains</td>
</tr>
</tbody>
</table>

*Source: BCG Analysis*
Trend towards pivoting at Product-Service transformation business model picking up in recent times

PRODUCT & SERVICE APPROACH
What are the right products and services to grow?

PRODUCT & SERVICE INTRODUCTION
How do we design a new product & services and find market traction?

PRODUCT & SERVICE GROWTH
How do we drive rapid adoption at scale?

PRODUCT & SERVICE TRANSFORMATION
How do we chart a new trajectory for a stable or flagging product & service?

DEVELOPMENT
New ideas tested and operationalized

INTRODUCTION
Product-market fit yet to be found

GROWTH
Demand accelerates, market expands rapidly

MATURITY
Demand levels off, product stabilizes

DECLINE
Product loses appeal, demand drops

Source: Press Search; BCG Analysis
Pivot towards an integrated (Product-Service) approach becoming a key growth driver...

1. PRODUCT & SERVICE SUITE INTRODUCTION
   How do we design a new product and services suite?
   Introducing a service alongside the product during the product development and introduction phase creates a comprehensive solution for customers and market pull.

2. PRODUCT & SERVICE SUITE GROWTH
   How to we drive rapid adoption at scale?
   Subscription-based services, maintenance contracts, and extended warranties provide opportunities for recurring income during product growth phase.

3. PRODUCT & SERVICE TRANSFORMATION
   How do we chart a new trajectory for a stable or flagging product?
   Integrated solution provider approach that leverages new technologies and heightens the customer experience, adding to shadow P&L and create competitive edge.

INTEGRATED SOLUTIONS

- Business model moving from a pure product focus to integrated solutions that drive further value for the customers
- Integrated solutions consider the customer journey in its entirety – developing new product, services and incentives and refining the revenue model.

Source: BCG Analysis
… resulting in a new ER&D strategy focused on using data, cross-engineering and hybridization of product

1. **DATA**
   - Engineering to leverage the wealth of data generated by the product to drive service offerings
     - Industries are prioritizing data-driven digital transformation, making it a central tenet of their ER&D strategies as they pivot to the service paradigm
     - ER&D teams are focusing on developing smart products, predictive maintenance solutions, and data-driven optimization techniques to enhance operational efficiency and customer experiences

2. **CROSS-ENGINEERING**
   - Ecosystem collaboration and open innovation beyond own organization
     - Traditional industries looking for fresh perspectives and complementary technologies from startups, research institutions, and service partners to accelerate innovation
     - ER&D will involve a more diverse range of stakeholders, leading to cross-industry solutions, faster time-to-market, and shared expertise

3. **PRODUCT-SERVICE HYBRIDIZATION**
   - Companies to bundle their products with complementary services to create additional value
     - ER&D teams are designing products that are not only functional but also support seamless integration with value-added services, enhancing customer experiences and loyalty

Source: BCG Analysis
NEED OF ER&D

- Millennials want to use the services for transporting from Point A to Point B (uberization) than owning a car due to either liking to drive different models or aligning with self-driving cars.
- The challenge with uberization is customer dissatisfaction over continuously changing the settings on each new car subscribed.

DESCRIPTION OF SOLUTION

- The solution customizes car settings (climate, seating, infotainment) based on customer preferences learned through data sharing with the IoT platform and analytics.
- It uses the IT Gateway to apply these preferences and adjust ECUs for intelligent personalization.

INNOVATION BRIEF

The solution will intelligently change the personalization of the new car subscription by continuously monitoring the past subscription of the vehicles by the same customer.

IMPACT

- Personalization is the benefit of this solution.
- It gives a feeling to the customer that they are using their own car, if the car model is same.
- If the car model is different, then based on data analytics best preferred personalization is provided.

ABOUT THE COMPANY

Company: Expleo
Megatrend: Service Orientation
Expleo | Smart Mobility using IoT platform - ThingWorx

- An infotainment application: Gathers user settings data from ECU and sends it on IoT platform.
- Applicable to all users.

- Stores multiple user preferences securely.
- Applies analytics and understands user behavior.
- Makes data compatible for all car models.

- User settings applied back when user subscribe the car again.
- User requests for the service either through Mobile App, Web App or from the rental agency network.
TCS | IoT enabled - Predictive Maintenance

ABOUT THE COMPANY
Company: TCS
Megatrend: Product to Service

NEED OF ER&D
- Supplier: Lack of Inhouse integration capabilities, Spares and Supply chain issues and Longer Problem Resolution time
- Distributor: Value Chain Optimization and Limited ecoSystem Play
- End Customers: Asset Downtime, Efficiency and Reliability, Stranded data and Silo Operations, Cost Pressure, Multi Standard and Multi Interfaces

INNOVATION BRIEF
It is a Smart Industrial IoT product that optimizes MRO, sustainability, performance, predictive maintenance, OEE, and reliability to create actionable insights

DESCRIPTION OF SOLUTION
- TCS developed “RS INDSTRIA,” an industry-first IoT platform based on AWS IoT, serving multiple industries
- They provided contextual IoT knowledge, digital manufacturing expertise, remote diagnostics, and predictive services to build this scalable product
- Key TCS solutions include OTDO, iHAL, AWS Greengrass, CDD, aADF frameworks, and insights for predictive maintenance and operational efficiency

IMPACT
- 14% energy optimization, high asset availability through predictive maintenance, and significant OEE improvement
- Interoperable, scalable, cloud-centric IoT for versatile device and OT component integrity
- Ensured Data-To-Decision (D2D) and Bringing-Life-To-Components (BLTC) to bring resilient to industry needs and auto scale on capacity

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5 Mega trends that will affect ER&D

1. POPULATION & SKILL INVERSION: SHIFTING SKILLS AND TALENT POOLS

Source: BCG Analysis
Demographic Impact: all feel it, but some (significantly) more than others

TOTAL LOSS IN WORKING AGE POPULATION IN AffECTED COUNTRIES: ~400 MILLION BY 2050

Comparison of population decline and working age population gap
Decrease in working age population 2050 - 2020

Source: UNDP zero migration scenario, World Bank, BCG analysis
Gains and losses: Significant shifts in working age population

**OVERALL: 345M NET LOSS OF WORKING AGE POPULATION**
Top 10 countries\(^1\) - 2020 vs. 2050

- China
- Japan
- Russia
- USA
- Korea
- Germany
- Italy
- Thailand
- Spain
- Ukraine

**775M NET GAIN OF WORKING AGE POPULATION**
Top 10 countries\(^2\) - 2020 vs. 2050

- India
- Nigeria
- Pakistan
- Dem. Repub. Of Congo
- Ethiopia
- Tanzania
- Egypt
- Uganda
- Philippines
- Bangladesh

---

1. 10 countries with greatest absolute decreases in population age 15-64, in order: China, Japan, Russia, USA, Korea, Germany, Italy, Thailand, Spain, Ukraine
2. 10 countries with greatest absolute increases in population age 15-64, in order: India, Nigeria, Pakistan, Dem. Repub. Of Congo, Ethiopia, Tanzania, Egypt, Uganda, Philippines, Bangladesh

Source: BCG ER&D Survey 2023; BCG Analysis
Aging population affecting ER&D talent availability in hotspots like Japan, Germany and the UK

Japan (Ministry of Economy):  
Japan will face a deficit of 789,000 software engineers by 2030.

Demand for non-Japanese engineers is growing.

Germany: In 2020, there were three workers for every person over 65, while in 2035 the ratio will drop to 1:1.

Unavoidable demographic change represents major challenges to the German economy, correcting economic growth forecasts from 1.8% down to 1.5%.

UK: There is an estimated shortfall of over 173,000 workers in STEM sectors in U.K.

Over 150 engineering leaders have urged the government to tackle the UK’s skills shortage by embedding engineering into the national curriculum.

Source: Handelsblatt, Bertelsmann Stiftung, Bundesfinanzministerium, S&P Global, Guardian, The Local, Japan Times, IET
Which will affect ER&D sourcing patterns and operating models under a new ‘Global’ ER&D strategy

GLOBAL ENGINEERING STRATEGY

1. “One person, many teams”
   Switch key teams (and if needed full department) to operate in a matrix structure and overcome skill shortages

2. Broaden the reach
   Build a globally recognizable employer brand and value proposition to attract talent

3. Create new depth
   Build dedicated bridges for global geo-diverse junior talent hiring pools

GLOBAL R&D STRATEGY

1. Minimum viable process
   Run a pragmatic decision-making process to ensure best projects survive with given talent

2. Remain mission-first
   Create new hubs where talent is available and growing or outsource to competent partners

3. Mix and match diverse teams
   Developing diverse teams with local and migrant talents

Source: BCG Analysis
Appendix

Sector Deep Dives and Case Studies
Aerospace & Defence sector Deep dive
Aerospace & Defence: ER&D spend expected to reach $90-120B by 2030 growing at ~7-8% CAGR with high focus on additive manufacturing & tech in defence

SECTOR’S ER&D SPEND EXPECTED TO REACH $90-120B BY 2030...

+7-8%

$50B - $70B

$90B - $120B

2023E

2030F

Sector’s Business ER&D Spend ($B)

...WITH ADDITIVE MANUFACTURING & CYBER SECURITY AS KEY FOCUS AREAS IN THE SECTOR...

Additive Manufacturing in Components
Cybersecurity for Aerospace & Defense
AI for Mission Planning & Decision Making
Sustainable Aviation & Electric Propulsion
Hypersonic Flight & Space Tourism
Urban Air Mobility & Flying Taxis
Swarming Drones & Autonomous Vehicles
Space Debris Removal & Cleanup Initiatives
Advanced Satellite Comm & Data Sharing
Quantum Key Distribution for Secure Comms

% sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years

% of sector’s ER&D spend on digital engineering

SECTOR’S BUSINESS ER&D SPEND EXPECTED TO REACH $90-120B BY 2030...

% sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years

...WITH ADDITIVE MANUFACTURING & CYBER SECURITY AS KEY FOCUS AREAS IN THE SECTOR...

Additive Manufacturing in Components
Cybersecurity for Aerospace & Defense
AI for Mission Planning & Decision Making
Sustainable Aviation & Electric Propulsion
Hypersonic Flight & Space Tourism
Urban Air Mobility & Flying Taxis
Swarming Drones & Autonomous Vehicles
Space Debris Removal & Cleanup Initiatives
Advanced Satellite Comm & Data Sharing
Quantum Key Distribution for Secure Comms

% sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years

...ACCOMPANIED BY SHARE OF DIGITAL ENGINEERING REACHING ~50%

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Three major shifts will strategically impact and lead to increased aerospace & defence ER&D

**SWITCH TO MORE FUEL-EFFICIENT AIRCRAFT**

Sustainable Aviation Fuel, Open rotors / bigger fans, New wings / airframe architectures, Hydrogen fuel are technologies to increase fuel efficiencies of aircrafts

Driven by:
- IATA members’ decarbonization commitments by 2050
  - 0% Net CO₂ increase after 2020 (carbon neutral growth)
  - 50% Reduction in net aviation emissions by 2050 (2005 levels)
- 20-30% reduction in costs due to higher fuel efficiency

**TACKLING CONCERNS OF CYBERSECURITY**

Innovation in products, systems and services of ER&D players in aerospace & defence, e.g., encryption, quick response system for detection, etc.

Driven by:
- Complex infrastructure of multiple interconnected systems, leveraging plug-&-play software from the industry has increased risk of cyber attacks

**ADDITIVE MANUFACTURING CAPABILITIES (E.G.,: 3D PRINTING)**

Driven by:
- Increasing pressure on OEMs for reduced product development timelines (80% reduction in tooling manufacturing lead time)
- Up to ~40% savings in tooling costs dependent on tooling family (avg. ~20%)

Source: BCG Analysis
Key concern in the industry is sustainability as focus on net-zero increases, along with cybersecurity & skill-gap as sector becomes increasingly more connected.

### CONCERNS HIGHLIGHTED BY ER&D LEADERS IN THE SECTOR

<table>
<thead>
<tr>
<th>Concern</th>
<th>% of Total Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability</td>
<td>85%</td>
</tr>
<tr>
<td>Increasing Cybersecurity Threats</td>
<td>80%</td>
</tr>
<tr>
<td>Talent Shortage and Skill Gap</td>
<td>75%</td>
</tr>
<tr>
<td>Geo-Political Uncertainties</td>
<td>70%</td>
</tr>
<tr>
<td>Rapid Technological Obsolescence</td>
<td>65%</td>
</tr>
<tr>
<td>Regulatory and Compliance Challenges</td>
<td>40%</td>
</tr>
<tr>
<td>Data Privacy Concerns</td>
<td>30%</td>
</tr>
<tr>
<td>Circular Economy Initiatives</td>
<td>20%</td>
</tr>
<tr>
<td>Interconnected Ecosystem Complexity</td>
<td>20%</td>
</tr>
<tr>
<td>Ethical and AI Bias</td>
<td>15%</td>
</tr>
</tbody>
</table>

Multiple choices permitted per respondent. % shows the percentage of experts within a class that determined the choice as a future challenge.

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
ABOUT THE COMPANY

Company: Collins Aerospace
Sector: Aerospace

INNOVATION BRIEF

Provides seamless connectivity in the air and on ground using different communication media

NEED OF ER&D

Acquiring, maintaining, and operating a fleet of aircraft Ground Support Equipment (GSE) represents a substantial capital expenditure

- GSE fleet owners and managers are continually looking to monitor, control, and contain these costs
- Among greatest opportunities for cost savings are improving maintenance efficiencies, “right-sizing” the fleet, and reducing costs resulting from fuel wastage and vehicle accidents

DESCRIPTION OF SOLUTION

- Solution links connected ground assets and ADS-B equipped aircrafts into an effective tarmac data collection and monitoring tool by providing information of the aircraft upon approach, monitoring the airside (aircraft, vehicles, equipment) on ground in real-time, and sending alerts to operators
- RampNetSM uses IoT-based long-range and low power sensor network to track both motorized and non-motorized GSEs
- 24x7 without dependency on cellular networks or WiFi

IMPACT

Implemented in Cochin International Airport

- Low-cost telemetry infrastructure without expensive cellular network recurring charges
- Low-cost solution replaces expensive Advance Surface movement guidance and control systems (A-SMGCS)
- Data integration contributing to Airports, Airlines and ATC database, optimizes operations and reduce carbon footprint
Collins Aerospace | RampNetSM - Connectivity in air and on-ground
Cyient | Fuel Efficient Aircraft Engine

ABOUT THE COMPANY
Company: Cyient
Sector: Aerospace

NEED OF ER&D
- Supporting customer in developing lighter, more economical, greener engines through Multi-Disciplinary design optimization to meet component, modules and system design goals and Manufacturing Engineering & Process Planning

INNOVATION BRIEF
World’s Most Fuel-Efficient Aircraft Engine saving over three million metric tonnes of CO2 emission, 5% productivity enhancement.

DESCRIPTION OF SOLUTION
- Greener Engine that delivers game-changing environmental performance. Which include Design to build solutions for engine part families (Compressors, Combustors, Rotors, Cases, Turbines, etc.)
- Prototype build and test support (onsite support & documentation for testing), Installation & Certification support, including technical publications, perform the testing operations at the Aero Engine OEM’s facility on the engine to lower weight and cost, which helped improve Fuel Efficiency

IMPACT
- The solution delivered substantial benefits including improves fuel burn by 16+% compared to today’s top engines, Exceeds strict emission regulations by more than 50%
- Reduces airplane carbon emissions by 3100K tonnes per year, equivalent to growing over 900,000 trees, Reduces aircraft noise footprints by more than 75%
Cyient | Fuel Efficient Aircraft Engine
Automotive sector
Deep dive
Automotive: ER&D spend expected to reach $460-540B by 2030 driven by xEV, connected mobility and vehicle software priorities

**Automotive Business ER&D Spend**
- Expected to inch towards $460-540B by 2030 growing at 8-9% CAGR...
- $250B - $300B in 2023E
- $460B - $540B in 2030F

**With Electrification, Connected Vehicles & Software as Top 3 ER&D Priorities for the Sector**
- Electrification & xEV: 60%
- AV & Connected Mobility: 53%
- Software & Connectivity: 38%
- Vehicle Design Innovations: 28%
- Enhanced Vehicle Safety & ADAS: 26%
- Mobility-as-a-service: 17%
- Subscription-based ownership: 15%
- Circular Economy Initiatives: 13%
- 3D Printing & Additive Manufacturing: 9%
- VR & AR in Showrooms & Training: 4%

**ACCOMPANIED BY SHARE OF DIGITAL ENGINEERING INCREASING BY 22PP**
- 61% in 2030F
- 39% in 2023E

% sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Three trends will strategically impact automotive ER&D

**ELECTRIC POWERTRAINS**
Move away from ICE vehicles to electric-powered engines

Driven by:
- Increasing advantage of EV vs. ICE
- Battery cost reductions
- Reduced adoption barriers (e.g., range, charging stations)
- Changing user sentiment

**VALUE CHAINS WILL RADICALLY CHANGE WITH HW/SW DECOUPLING**
Unbundling of Hardware and Software in automotive sector

Driven by:
- Need for improved speed to market in the automotive industry
- Own the platforms while sourcing software from others

**CONNECTED CAR AND IN-CAR TECHNOLOGIES**
Connected car services to enhance customer experience and offer new features

Driven by:
- Technological readiness: Increasingly more cars to be connected
- Strong investments: Big tech moves into automotive sector
- New Business for OEMs: Significant cost-savings and new business opportunities
- Customer expectations: Majority of future car features to be software-based

Source: BCG Analysis
Talent shortage & skill gap is the key challenge faced by automotive ER&D players; need for cross-functionally skilled workforce with new niche skills.

**CONCERNS HIGHLIGHTED BY ER&D LEADERS IN THE SECTOR**

- Talent Shortage and Skill Gap: 74%
- Sustainability: 62%
- Geo-Political Uncertainties: 51%
- Regulatory and Compliance Challenges: 49%
- Increasing Cybersecurity Threats: 49%
- Rapid Technological Obsolescence: 47%
- Shifting Consumer Preferences: 40%
- Interconnected Ecosystem Complexity: 30%
- Data Privacy Concerns: 26%
- Ethical and AI Bias: 9%

*% of total respondents*

**KEY SKILLS REQUIRED BY ER&D PLAYERS IN THE SECTOR**

- **ELECTRICAL CIRCUIT THEORY AND BASIC COMPONENTS**
- **MECHANICS**
- **SOFTWARE DEVELOPMENT METHODOLOGIES**
- **MICROCONTROLLER-BASED SYSTEMS**
- **CAD SOFTWARE FOR BASIC 2D/3D MODELING**
- **ONE CODING LANGUAGE (JAVA, PYTHON, ETC.)**
- **SOFTWARE TESTING PRINCIPLES AND DEBUGGING TECHNIQUES**

*Multiple choices permitted per respondent. % shows the percentage of experts within a class that determined the choice as a future challenge.*

**Source:** Capital IQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Jaguar Land Rover | Software Over The Air Updates with Dual Memory Architecture

**ABOUT THE COMPANY**

**Company:** Jaguar Land Rover  
**Sector:** Automotive

**NEED OF ER&D**

Time, cost and effort for both the customer and JLR to update software
- Software update using Diagnostics requires physical presence of the vehicle at dealer’s place
- Vehicle should be kept in Ignition ON state which adds additional carbon footprint
- Each ECU needs to be updated separately and each takes ~1 hour for a successful update
- If update is unsuccessful it takes more time

**DESCRIPTION OF SOLUTION**

-Introduced dual memory architecture for **seamless software updates** to vehicle where it can be updated while in **park mode** as well as drive mode; this brings down recalls of the vehicles due to software issues.
- By implementing dual memory, **software is downloaded and updated in the background** in smaller deltas while the original software is running from the active memory; this **reduces failures due to software updates** because the active memory always have the last working software.

**INNOVATION BRIEF**

Introducing dual memory architecture for Electronic Control Units (ECU) to deliver new capabilities and fix existing issues over the air (SOTA) to the vehicle.

**IMPACT**

- 7M+ customers saving $300M+ annually for JLR for a single ECU; future software updates to their vehicle without having to visit their Retailer.
- Around 65 ECU’s gets updated remotely which is cost effective and saves lot of engine running time and emissions.
Jaguar Land Rover | Software Over The Air Updates with Dual Memory Architecture
NEED OF ER&D

• To comply with the stringent EU7 emission norms, exhaust emission from vehicles must be further reduced. This necessitates heating of the catalyst in the exhaust especially under low operating temperatures in order to increase the conversion efficiency.

DESCRIPTION OF SOLUTION

• Burner module is introduced in the exhaust pipe of the diesel vehicle in order to heat up the catalyst and reduce harmful exhaust gas emission. The burner is powered by a spark plug and Ignition coil system. The Ignition system needs to be controlled precisely by the ECU software in order to achieve optimum emission reduction.

• The Burner Ignition system is new to Diesel segment and had to be entirely re-engineered from spark ignition used in Gasoline engines.

IMPACT

• Better conversion efficiency of exhaust catalyst independent of the engine operating temperature

• Reduction of Diesel exhaust emissions of NOx, unburnt HC, CO and Particulate Matter

• Compliance with upcoming Emission norms worldwide, including EU7

• Improve Air quality and reduce pollution caused due to diesel vehicles
Bosch | Diesel Exhaust Burner Ignition
ABOUT THE COMPANY

Company: Tata Technologies
Sector: Automotive

INNOVATION BRIEF

Innovation to convert the existing ICE vehicle to EV without developing a new EV platform through a novel PMXU approach and packaging solution of electrical systems.

NEED OF ER&D

- OEMs are in a race to launch new electric vehicles, however, associated high product development cost is one of the major challenges that OEMs are facing.
- To reduce these costs, OEMs are exploring the conversion of existing ICE platforms to EVs, which would use 70% carry-over parts. However, this comes with challenges of space and packaging constraints, part commonality with ICE vehicles, and reduced manufacturing flexibility.

DESCRIPTION OF SOLUTION

- A novel ICE to EV conversion process templatized for packaging the electrical sub-system with minimal changes to other sub-systems based on changes in weight distribution and packaging requirements.
- It is based on the PMXU approach (P – Carry over, M – modified, X transfer, U- unique). It is backed by our NPI process that is based on clearance of checkpoints and gateway audits. Digital validation is used throughout the project, resulting in timely detection of errors & reduced costs.

IMPACT

- EV launch time reduction from 28 months to 18 months from concept to production.
- Product development cost reduced by 30% (no. of prototypes typically 48 vs 35 for EV, other costs).
- Manufacturing Capex reduction by 20%.
Tata Technologies | Conversion of ICE to EV

**Carryover/ Modify/ Unique Part Strategy**

A strategy has to be built around which parts of the ICE vehicle will be reused "AS-IS" in EV and which ones will be modified for each commodity.

- **Interior & Seats**
  - Carryover
  - Modified
  - Unique

- **Ev Powertrain**
  - Carryover
  - Modified
  - Unique

- **Frt Suspension**
  - Carryover
  - Modified
  - Unique

- **Rear Suspension**
  - Carryover
  - Modified
  - Unique

- **Exteriors**
  - Carryover
  - Modified
  - Unique

Note: Numbers mentioned in the block are in K and rounded for illustration purposes.

**Cooling system layout**

- **AC Pipes**
  - BCS Pump
  - BCS Hoses
  - Compressor
  - Condenser
  - Evaporator + TCV
  - Cabin Air Heater
  - Battery
  - Chiller + TCV
  - Glycol + Water
  - TY Battery

**Major unique parts developed**

- **Front Suspension**
  - Change in FAW results in modifying the Front spring stiffness
  - Damping force is required to be tuned

- **Brakes**
  - Brakes to be re-evaluated for the re-distributed FAW/RAW

- **Rear Suspension**
  - Change in RAW, results in modifying the Rear spring stiffness
  - Damping force is required to be tuned
  - Rear bump stopper height to be adjusted for any ride height changes based on RAW
  - Ground Clearance management

- **Wheels & Tyres**
  - Rims to be re-evaluated for new handling due to weight re-distribution
  - Tyres to be checked for load & speed ratings
  - Low rolling resistance tyres
Consumer Electronics sector Deep dive
Consumer Electronics: ER&D spend expected to reach $250-400B by 2030 owing to impact of innovations in computing, display technologies and AI

CONSUMER ELECTRONICS ER&D SPEND EXPECTED TO REACH ~$250-400B BY 2030 GROWING AT ~7-8% CAGR...

Sector’s Business ER&D Spend ($B)

$150B - $230B
$250B - $400B

2023E
2030F

... WITH QUANTUM, FLEXIBLE DISPLAY & AI AS TOP 3 ER&D PRIORITIES OF THE SECTOR...

- Quantum Computing’s Impact on CE
- Foldable and Flexible Display Technologies
- Integration of AI and Voice Assistants
- Wearable Health and Fitness Technologies
- Sustainability and Eco-Friendly Gadgets
- Home Automation and Smart Appliances
- 5G-Powered Smart Devices and Connectivity
- Augmented and Virtual Reality Experiences
- Personalized Content Streaming Services
- Enhanced Camera and Imaging Technologies

% sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years

% of sector’s ER&D spend on digital engineering

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
4 Trends Shaping the Consumer Electronics & Consumer Appliances industry

**AI-LED FASTER MARKET LAUNCHES**
Speeds up design validation and time-to-market & facilitates new material commercialization through enhanced simulations.

**Driven by:**
- Need for quick turnaround of product designs
- New product innovation to attain higher performance standards

**FOLDABLE & FLEXIBLE DISPLAY TECH**
Flexible displays, made on substrates like plastic, paper, metal, or flexible glass.

**Driven by:**
- Demand for aesthetics by consumers
- Extended beyond smartphones to other consumer electronics incl. smart watches, tablets, etc.

**CONNECTIVITY: SMARTER DEVICES & HOMES**
Focus on interoperability to avoid using different apps to control different devices & instead use a common app as central hub.

**Driven by:**
- Increase in internet usage & uptick in regulatory trends are driving the acceptance of Interoperability
- AI tech integrated into various consumer electronics to enhance user experience and to offer value-added support

**SUSTAINABLE ELECTRONICS**
Focus to make consumer electronics supply chain and usage more sustainable.

**Driven by:**
- Sustainable Product Offerings: Advanced sensors for energy conservation etc.
- Supply chain decarbonization for consumer electronics to meet Net-Zero emissions by 2030

*Source: BCG Analysis*
Geopolitical uncertainties, rapid technological obsolescence and talent shortage are top three challenges faced by ER&D players in consumer electronics space

### Concerns Highlighted by ER&D Leaders in the Sector

<table>
<thead>
<tr>
<th>Concern</th>
<th>% of Total Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geo-Political Uncertainties</td>
<td>86</td>
</tr>
<tr>
<td>Rapid Technological Obsolescence</td>
<td>76</td>
</tr>
<tr>
<td>Talent Shortage and Skill Gap</td>
<td>71</td>
</tr>
<tr>
<td>Shifting Consumer Preferences</td>
<td>62</td>
</tr>
<tr>
<td>Sustainability</td>
<td>52</td>
</tr>
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</tr>
<tr>
<td>Regulatory and Compliance Challenges</td>
<td>33</td>
</tr>
<tr>
<td>Data Privacy Concerns</td>
<td>29</td>
</tr>
<tr>
<td>Ethical and AI Bias</td>
<td>24</td>
</tr>
<tr>
<td>Interconnected Ecosystem Complexity</td>
<td>19</td>
</tr>
</tbody>
</table>

Multiple choices permitted per respondent. % shows the percentage of experts within a class that determined the choice as a future challenge.

### Key Skills Required by ER&D Players in the Sector

- Microcontroller, their applications, & programming
- Software development techniques
- Electrical circuit theory and basic components
- Proficiency in 1 coding language

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Samsung Research | Carbon Emission Awareness & Reduction using AI power energy management in Smart Homes

ABOUT THE COMPANY

Company: Samsung Research
Sector: Consumer Electronics

INNOVATION BRIEF

SmartThings Energy, employs AI powered algorithms to reduce the energy consumption by smart devices, lowering the resulting carbon emission. It also provides detailed real-time carbon footprint information based on the energy usage. consumption of RAN leading to energy savings.

NEED OF ER&D

- Global carbon emissions hinge on household energy use; viz. USA averages 16 tons/person, with homes responsible for 20%
- Smart home users must grasp this, curbing energy consumption by their smart home devices (AC, fridge, washer etc.) for impact

DESCRIPTION OF SOLUTION

- The solution details users’ carbon footprint based on smart home energy use
- AI-driven algorithms on smart devices minimize this carbon footprint by lowering energy consumption
- SmartThings Energy’s AI Energy Mode saves 70% energy on select cycles and devices
- Participating in Automatic Energy Demand Response Program through the solution, users earn rewards by cutting peak energy use

IMPACT

- Provides user a detail analysis of their carbon footprint which intern will be used to plan employing an energy efficient provider or adding green energy producer like solar panel
- Managing and automating connected devices it helps consumers to gain insights into their energy use, thereby inspiring energy-saving behavior, reducing costs and helping to facilitate demand response measures that minimize stress on the grid
Samsung Research | Carbon Emission Awareness & Reduction using AI power energy management in Smart Homes
Tech Mahindra | Smart Mixer

ABOUT THE COMPANY

Company: Tech Mahindra
Sector: Consumer Electronics

INNOVATION BRIEF

IA stand mixer that is designed for assisted cooking using Auto Sense Technology, Built-In Smart Scale, and IOT features for enhanced cooking experience.

NEED OF ER&D

• With the rise of connected home technology, consumers are increasingly looking for ways to incorporate smart features into their home appliances. The smart mixer is trying to full-fill this need with its innovative features.

DESCRIPTION OF SOLUTION

• Auto Sense Technology actively monitors changes in texture and viscosity through motor torque feedback to optimize mixing performance. Mobile/tablet connectivity with the smart mixer provides app based guided recipes.

• Built in smart scale precisely measures ingredients in the mixing bowl based on the guided cooking recipe. Bidirectional rotation of the blending mechanism helps in better mixing. New attachments design helps improve mixing of ingredients.

IMPACT

• The appliance features optimized mixing performance. OTA for new recipes and software updates.

• Wi-fi feature for connected appliance experience and app-based guided cooking.

• The device features voice control for hands-free cooking and a digital display for speed, time, and weight information.
Tech Mahindra | Smart Mixer

PRODUCT INNOVATION OVERVIEW

A stand mixer that is designed for assisted cooking using Auto Sense Technology, Built-In Smart Scale, and IoT features for enhanced cooking experience.

PROBLEM OR OPPORTUNITY

With the rise of connected home technology, consumers are increasingly looking for ways to incorporate smart features into their home appliances. The smart mixer is trying to full-fill this need with its innovative features.

PRODUCT INNOVATION OVERVIEW

Auto Sense Technology actively monitors changes in texture and viscosity through motor torque feedback to optimize mixing performance. Mobile/tablet connectivity with the smart mixer provides app based guided recipes. Built in smart scale precisely measures ingredients in the mixing bowl based on the guided cooking recipe. Bidirectional rotation of the blending mechanism helps in better mixing. New attachments design helps improve mixing of ingredients.

PRODUCT INNOVATION BENEFITS

Optimized mixing performance will prevent under/over mixing for specific recipes. OTA feature allows for new recipes and software updates. Wi-fi feature enables connected appliance experience and app based guided cooking. Inbuilt scale helps with guided cooking and precise weighing of ingredients resulting in better cooking. Voice control of the device for hands free cooking. Digital display on device for displaying details of speed, time and weight.

A SMART MIXER FOR ASSISTED COOKING

Tech Mahindra partnered for design and development of esthetics & features for Smart Mixer for enhanced cooking experience & futuristic appearance. Smart mixer enables assisted cooking utilizing Auto Sense Technology, Built-In Smart Scale and IoT features. The Auto Sense Technology actively monitors changes in texture and viscosity through motor torque feedback to optimize mixing performance. The Wi-Fi feature enables a connected appliance experience and app-based guided cooking. The inbuilt scale aids in guided cooking and precise weighing of ingredients, resulting in better cooking.

CES Innovation Award Honoree, USA
Energy, Utilities and Oil & Gas sector Deep dive
Energy, Utilities and Oil & Gas: Increased focus on green technologies & digital expected to take sector’s business ER&D spend towards $175-220B by 2030...

...WITH DECARBONIZATION, ENERGY-EFFICIENCY & RENEWABLE ENERGY AND DIGITIZATION AS TOP ER&D PRIORITIES...

$110B - $140B

$175B - $220B

2023E

2030F

% sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years

Decarbonization & CCUS Technologies
74%

Energy Efficiency & Demand Response solns
47%

Transition to Renewable Sources
42%

Digitalization in Oil & Gas Operations
32%

Energy Storage Breakthroughs
32%

Electric Vehicle Charging Infrastructure
21%

Smart Grids & Energy Management
21%

Offshore Wind & Floating Solar Installations
16%

Distributed Energy Resources Integration
16%

Hydrogen Fuel Cell Advancements
0%

% of sector’s ER&D spend on digital engineering

2023E

2030F

20%

42%

+22pp

Multiple choices permitted per respondent. % shows the percentage of experts within a class that determined the choice as a future challenge.

Source: CapitalIQ, BCG ER&D Survey 2023 n=281, Press Search; BCG Analysis
Two major trends are driving ER&D in the sectors

**NET-ZERO TRANSITION:**
- **Low-emission technology**
  - Renewable energy, esp. solar: Global Solar PV market is expected to grow significantly from 2023 until 2030
    - Solar PERC cell technology dominates, to be replaced by TOPCon & HJT technologies
  - CCUS: Carbon capture capacity projected to grow significantly
  - Increase in nuclear fission R&D: Emergence of several startups & investments by O&G players

**DIGITIZATION:**
- Improve efficiency with technology
  - New technologies using of AI/ML, drone, etc. in power generation through renewables and conventional sources – e.g., wind design & array layout, predictive maintenance, drone for inspections, etc.
  - Use of digital twin to simulate development, operations, etc. – thus, lowering costs, improving efficiency, etc.

**Power Generation**

**Grid Modernization:**
- Increased volume of data from grid assets—e.g., smart grid, smart meters, etc. to improve efficiency of transmission & distribution
- Integration of renewable energy to the grid; introduction of storage, specially for renewables

**Oil & Gas**

**Biofuel usage** to grow; R&D focus on fuels derived from algae & microbes

**Note:**
1. Stated Policies Scenario reflects the impact of existing policy frameworks and today’s announced policy intentions
2. Sustainable Development Scenario assuming all new policies proposed by governments take place and the world will comply to COP21 and hence rise of temperatures will stay within 1.5°-2°C

Source: BCG Analysis
Key concerns from industry leaders include interconnected complexities driven by geo-political uncertainties, and skill gap due to increasing digitization.

### Key Skills Required by ER&D Players in the Sector

- **Big Data & Analytics**
  - Version Control Systems (Git, SVN) Collaborative Coding

- **AI/ML and Digital Technologies**
  - Testing & Debugging Techniques

- **Data Visualization Techniques & Charting Libraries**

### Concerns Highlighted by ER&D Leaders in the Sector

- Geo-Political Uncertainties: 79%
- Interconnected Ecosystem Complexity: 68%
- Talent Shortage and Skill Gap: 68%
- Sustainability: 63%
- Regulatory and Compliance Challenges: 58%
- Rapid Technological Obsolescence: 53%
- Data Privacy Concerns: 37%
- Shifting Consumer Preferences: 32%
- Interconnected Ecosystem Complexity: 26%
- Ethical and AI Bias: 16%

Multiple choices permitted per respondent. % shows the percentage of experts within a class that determined the choice as a future challenge.

**Source:** CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Honeywell | Ethanol to Jet Fuel

ABOUT THE COMPANY
Company: Honeywell
Sector: Energy, Oil & Gas, and Utilities

INNOVATION BRIEF
Ethanol-To-Jet Fuel (ETJ) is a processing technology that allows producers to convert corn-based, cellulosic, or sugar-based ethanol into Sustainable Aviation Fuel (SAF). SAF is a high-quality, renewable jet fuel with similar properties to conventional jet fuel.

NEED OF ER&D
• The demand for SAF is increasing, but the aviation industry is facing a shortage of traditional SAF feedstocks like vegetable oils, animal fats, and waste oils.
• However, there is a readily available and economically viable alternative - ethanol.

DESCRIPTION OF SOLUTION
• Honeywell’s ETJ process leverages more than a decade of Honeywell UOP’s Ecofining experience, low process carbon intensity, and high yield of the jet as proven by UOP’s track record in catalyst development and ability to economically scale from 30 thousand to a billion gallons per year.
• ETJ technology is not dependent on the type of ethanol used and does not require high-purity ethanol or more expensive feedstock.

IMPACT
• This represents a critical development in the drive to meet the 2030 sustainable aviation fuel (SAF) mandates and India’s 2070 emission reduction targets.
• ETJ process has the potential to reduce greenhouse gas (GHG) emissions by 80% on a total lifecycle basis, compared to petroleum-based jet fuel.
• It has an overall distillate yield (including both renewable jet and renewable diesel) of over 90% on a carbon basis.
Honeywell | Ethanol to Jet Fuel

4. SUSTAINABLE AVIATION FUEL (SAF) BLEND
Renewable jet fuel from the ethanol to jet process is blended with conventional jet fuel for use in flight.

3. ETHANOL TO JET
Ethanol to jet technology efficiently converts ethanol into highly refined sustainable jet fuel with similar properties to conventional jet fuel.

2. ETHANOL PLANT
Renewable ethanol is supplied to ethanol and processed to produce high-efficiency ethanol.

1. FEEDSTOCK SUPPLY
Sources of ethanol: primarily corn grain and sugarcane are ethanized.

Honeywell
FUELING THE FUTURE FOR CLEANER SKIES
Take off with UOP’s ethanol to jet (ETJ) process technology. The next generation of renewable fuels.

BENEFITS OF ETJ
- High jet fuel quality
- Lower CAPX expenses
- Reduced GHG emissions
- Higher-yield energy

5. SUSTAINABLE AVIATION FUEL (SAF)
The resulting fuel from the fuel blending process (Sustainable Aviation Fuel) is a safe and effective fuel solution that delivers a cleaner, higher-performance fuel.
TCS | AI Digital Twin Boiler Combustion Thermal Power Plant

INNOVATION BRIEF
A Holistic solution for Thermal power plant through digital integration to optimizes combustion cost and emissions

NEED OF ER&D

• Growing environmental and economic pressure on coal-fired power plants to operate with high efficiency, reduced emissions

• Modern coal power plants rely on complex network of sensors, actuators, digital controllers, and supervisory computers to operate and coordinate each of the plant subsystems

• Customer had tried many technological options to improve the operational KPI and was not successful

DESCRIPTION OF SOLUTION

• TCS IP2™, an intelligent digital solution that uses AI, IoT, and digital twin technologies

• TCS IP2™ Product leveraged to conceive and deliver Digital Twin within 1 year

• Explore 5 years data and extract the knowledge to AI/ML based Model

• Implemented scalable, modular Digital Twin for various plant operation process such as Combustion, Emission, Balance of Plant

IMPACT

• Combustion Digital Twin System reduced Operation cost by 1.5% (0.5-1.5 MUSD per year)

• Efficiency of Boiler increased by 0.5%

• Balance of Plant Twin reduced Auxiliary Power by 4.4%

• NOx Emission reduced by 8% and unburnt carbon rate by 1.6%
Healthcare & Medical Devices sector Deep dive
Healthcare & Medical Devices: ER&D spends expected to remain high in healthcare & medical devices making it the highest ER&D spender across sectors

BY 2030, SECTOR EXPECTED TO LEAD ER&D SPENDING, INCHING TOWARDS $460-620B...

$290B - $380B

2023E

$460B - $620B

2030F

% sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years

Includes prevention & tracking, diagnostics, therapies, surgeries, etc. 2. Multiple choices permitted per respondent. % shows the percentage of experts within a class that determined the choice as a future challenge Source: BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis

...WITH TELEMEDICINE, AI/ML IN DIAGNOSTICS, ROBOTICS & PERSONALIZED THERAPIES AS KEY FOCUS AREAS...

% of sector's ER&D spend on digital engineering

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Development of therapies increasingly involves technological collaboration, with growth coming from multiple new technologies.

### Healthcare & Medical Devices Research Trends

<table>
<thead>
<tr>
<th>Description</th>
<th>Driven by Need For</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consumer-driven digital health</strong></td>
<td>• Remote care&lt;br&gt;• Preventive care&lt;br&gt;• Wearable devices</td>
</tr>
<tr>
<td>Penetration of mobile devices and digital technologies is increasing the demand for remote services and innovative technologies that empower consumers to take a more active role in their healthcare.</td>
<td></td>
</tr>
<tr>
<td><strong>Real-world data and AI-enabled treatment and discovery</strong></td>
<td>• AI enabled analysis of medical imaging&lt;br&gt;• Machine-learning enabled drug discovery</td>
</tr>
<tr>
<td>Advances in data processing power and the exponential growth of medical data are enabling AI to lead to better care outcomes, including better targeting of therapies, early intervention, and improving productivity of care delivery.</td>
<td></td>
</tr>
<tr>
<td><strong>Rise of precision medicine</strong></td>
<td>• Multiplexed genetic profiling&lt;br&gt;• Personalised clinical therapeutics (e.g., CAR-T)</td>
</tr>
<tr>
<td>Precision medicine relies on increasingly detailed molecular characterisation of disease states using the biologic omics platforms to better individualise diagnostics, prognostics and therapeutics.</td>
<td></td>
</tr>
<tr>
<td><strong>Robotics in Surgery, etc.</strong></td>
<td>• Surgeries&lt;br&gt;• Hospital cleaning, medicine sorting, etc.&lt;br&gt;• Research laboratories</td>
</tr>
<tr>
<td>Robots aid healthcare workers in clinical settings, expanding their roles beyond the operating room to improve patient care.</td>
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</tbody>
</table>

Key concern in the industry is talent shortage & skill-gap, along with data privacy issues as digitization of healthcare & medical devices sector increases.

### Key Skills Required by ER&D Players in the Sector

<table>
<thead>
<tr>
<th>Key Skills Required</th>
<th>% of Total Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>AI/ML Algorithms &amp; Their Applications</td>
<td>85</td>
</tr>
<tr>
<td>Biotechnology, Biochemistry</td>
<td>65</td>
</tr>
<tr>
<td>Software Development Techniques</td>
<td>60</td>
</tr>
<tr>
<td>Big Data and Analysis</td>
<td>60</td>
</tr>
<tr>
<td>Knowledge of Electric System of Human Body</td>
<td>60</td>
</tr>
<tr>
<td>Debugging &amp; Collaborative Coding</td>
<td>50</td>
</tr>
<tr>
<td>Embedded Coding</td>
<td>40</td>
</tr>
<tr>
<td>Data Analytics Skills</td>
<td>40</td>
</tr>
<tr>
<td>Data Analytics Skills</td>
<td>25</td>
</tr>
<tr>
<td>Software</td>
<td>15</td>
</tr>
</tbody>
</table>

**Source:** Capital IQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Capgemini | Medical Device Connector (IoT in a box)

ABOUT THE COMPANY

Company: Capgemini
Sector: Healthcare and Medical Devices

NEED OF ER&D

- Create an automated mechanism for cost-effective transfer of system logs between medical device and IoT platform without human intervention while ensuring security and privacy of data in an existing healthcare environment and no regulatory re-certification

INNOVATION BRIEF

An effective solution for securely linking legacy medical devices and transmitting data to and from the chosen IoT platform with ensured security

DESCRIPTION OF SOLUTION

- Used an inexpensive SBC with Security and Connectively modules, and plug-n-play connection to any legacy Medical devices through standard ports
- Established mechanism for routine and automated upload of data
- Addressed IT/Privacy/Security concerns in healthcare environment
- HIPAA compliance wherever Clinical data is involved

IMPACT

- Security, hospital network independent, HIPAA compliance, Automated system Updates, Enabled remote connectivity, Extended Device life employing Predictive Maintenance, Reduced Green house emissions by reducing travel, inbuilt support for Software as Medical Device (SaMD) and tele-medicine solutions
Capgemini | Medical Device Connector (IoT in a box)
ABOUT THE COMPANY

Company: Tata Elxsi
Sector: Healthcare/Medical Devices

NEED OF ER&D

- Today the “doctor to population” ratio is alarming across the globe, in India it is at 1:1511
- TEngage is an effort to improve this ratio by making healthcare services more accessible esp. for the rural/remote/low economy locations
- Specialist hospitals at urban areas, would be able to quickly set up remote clinics at rural locations, cost efficiently with TEngage

DESCRIPTION OF SOLUTION

- Cloud-based, customizable, and compliant platform centralizes care team-patient communication with personalization and shared features
- Providers and patients access various healthcare services: appointments, video consults, chats and more
- Seamlessly integrates with hospital IT, deploys on any server (cloud or on-premises)
- Integrates clinical and non-clinical functions, offers insights for seamless digital, personalized care transition

INNOVATION BRIEF

An Omnichannel Care platform that acts as a “Digital Front Door” to essential healthcare services to provide a unified healthcare experience throughout the continuum of care

IMPACT

- Deliver Healthcare Anytime, with a unified patient experience
- Pick and plug modules for hospital specific needs
- White labelling to boost hospital brand
- Minimize Hospital Operational Cost and enable speedy, seamless deployments with cloud agnostic architecture
- Privacy and security with technical
- Improved market reach
Industrial (incl. construction) sector Deep dive
Industrials including Construction: ER&D spend driven by focus on advances in data backed ops, improving efficiency and quality of output through digital

**INDUSTRIAL ER&D SPEND EXPECTED TO REACH $250B-280B BY 2030 GROWING AT ~8-9% CAGR¹...**

$140B-$160B

% sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years

<table>
<thead>
<tr>
<th>Sector’s Business ER&amp;D Spend ($B)</th>
<th>2023</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>$140B-$160B</td>
<td></td>
<td></td>
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<tr>
<td>+8-9%</td>
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<tr>
<td>$250B - $280B</td>
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<td></td>
</tr>
</tbody>
</table>

**...WITH SUSTAINABILITY, AI-ENHANCED ANALYTICS & AUTOMATION AS TOP 3 ER&D SPENDS...**

<table>
<thead>
<tr>
<th>Topic</th>
<th>2023</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable Energy Integration</td>
<td></td>
<td>60%</td>
</tr>
<tr>
<td>AI-Enhanced Industrial Analytics</td>
<td></td>
<td>50%</td>
</tr>
<tr>
<td>Predictive Maintenance for Heavy Machinery</td>
<td></td>
<td>40%</td>
</tr>
<tr>
<td>Robotics &amp; Automation in Manufacturing</td>
<td></td>
<td>40%</td>
</tr>
<tr>
<td>Smart Factories &amp; Digital Twins</td>
<td></td>
<td>35%</td>
</tr>
<tr>
<td>Industrial IoT &amp; Industry 4.0 Transformations</td>
<td></td>
<td>30%</td>
</tr>
<tr>
<td>AR in Maintenance &amp; Training</td>
<td></td>
<td>25%</td>
</tr>
<tr>
<td>Blockchain for Supply Chain Traceability</td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>Sustainable Building Materials &amp; Construction</td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>Circular Economy in Industrial Operations</td>
<td></td>
<td>0%</td>
</tr>
</tbody>
</table>

**...ACCOMPANIED BY INCREASING SPEND ON DIGITAL ENGINEERING BY 21PP**

+21pp

% of sector’s ER&D spend on digital engineering

<table>
<thead>
<tr>
<th>Year</th>
<th>2023</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>32%</td>
<td>53%</td>
</tr>
</tbody>
</table>

1. Does not include major Chinese companies. Multiple choices permitted per respondent. % shows the percentage of experts within a class that determined the choice as a future challenge. **Source:** BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Three major shifts will strategically impact and lead to increased industrial ER&D spends

AUTOMATION & ROBOTICS
Use of control systems (such as computers or robots) & information technologies for handling different processes & machineries in industry for work otherwise done manually

Driven by:
- Deeper penetration of industrial robots driven by need for faster & more efficient industrial processes
- Industry driven by technological advancements in AI, IoT, etc.

PLATFORMIZATION
Development of basic structures for industrial tools, etc.; it uses re-use of parts saves money & time across platform and product launches

Driven by:
- Accelerated new product launches at lower costs
- Need for improved insights into product design for best performance through cross-functional input and engagement

DATA IN INDUSTRIALS
Data is being leveraged across sector to optimize factory operations, manufacturing processes, improve construction quality in construction sector, etc.

Driven by:
- Demand to optimize and improve manufacturing processes with analytics, digital twins & smart factories
- Predictive maintenance in industrials to ensure business continuity, etc.

Source: BCG Analysis
Key concern in the industry is talent shortage & skill-gap as digitization increases in an otherwise traditional industry.

<table>
<thead>
<tr>
<th>Concerns Highlighted by ER&amp;D Leaders in the Sector</th>
<th>% of Total Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talent Shortage and Skill Gap</td>
<td>85</td>
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<tr>
<td>Sustainability</td>
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<td>Data Privacy Concerns</td>
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<td>Increasing Cybersecurity Threats</td>
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<td>Regulatory and Compliance Challenges</td>
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<tr>
<td>Interconnected Ecosystem Complexity</td>
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<td>Rapid Technological Obsolescence</td>
<td>40</td>
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<tr>
<td>Shifting Consumer Preferences</td>
<td>25</td>
</tr>
<tr>
<td>Ethical and AI Bias</td>
<td>15</td>
</tr>
</tbody>
</table>

Multiple choices permitted per respondent. % shows the percentage of experts within a class that determined the choice as a future challenge.

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis

**Key Skills Required by ER&D Players in the Sector**

- **Big Data**
  - Data Analytics skills
- **ML Algorithms & Functions**
  - Data Analytics skills
- **Mechanics**
- **CAD, 2D-3D Modeling**
- **Materials and Their Properties**
  - Software Development Methodologies
  - At least one Programming Language (Java, C++, Python, etc.)

Data Analytics skills

Software
Schneider | Decarbonized steel enclosure

ABOUT THE COMPANY

Company: Schneider
Sector: Industrial incl Construction

NEED OF ER&D

- The steel Industry is responsible for around 7% of CO2 emissions globally
- This drives Schneider for an innovative solution and to align with 1.5°C scenario from CoP 21 agreement

INNOVATION BRIEF

First in class solution (Within segment / Schneider) of incorporating Green steel produced with renewable energy with the reduction of emissions in its scope 3 which limits carbon footprint and substantially boosts global goal of Net Zero emission

DESCRIPTION OF SOLUTION

- Schneider has developed a groundbreaking solution by replacing half of normal steel with decarbonized steel that transforms the traditional metal production process into sustainable one through which end user can significantly reduce their carbon footprint and contribute to a greener future
- By embracing this cutting-edge technology, businesses can achieve their goals while minimizing environmental impact

IMPACT

- This solution offers excellent environmental benefits without compromising the basic design intent, by reducing Co2 footprint by 34% (395 kgco2eq. savings/unit) thanks to 50% decarbonized steel
- Also, the other paybacks are 0% Single use Plastic, minimizing(0 to 5%) paper usage (leaflet) through QR code, 70% recycled cardboard in its packaging, with recyclability potential of 98%
Schneider | Decarbonized steel enclosure

“Only by choosing Decarbonized steel box you can save around 31,600 tree seedlings grown for 10 years.”

* Average done with a project with 5 columns

Why Decarbonized?
- It contains 50% of recycled steel manufactured with renewable energy
- -34% CO2 emissions

Current Special SF
1140 kg CO2 eq

New PanelSet SFN
745 kg CO2 eq

The Build-It-Faster Box
PanelSet SFN

Quick-fitting mounting plate
Semi-closed door hinges
Second door central handle
Roof with less fixation points
INNOVATION BRIEF

A 230V/415V AC circuit breaker for commercial and industrial use. Combines MCB and ELCB features, includes pre-detection for short circuits, overload & electric shocks.

DESCRIPTION OF SOLUTION

• A step-down transformer, followed by two current transformers (CTs), detects faults in phase or neutral lines by sending a low-voltage AC signal before powering the load
• Both CTs sense current, detect earth leakage, and identify human contact with phase or neutral lines
• A microcontroller monitors the circuit’s analog signal, detects earth leakage and output shorts before powering ON, and controls a relay to switch the circuit load

IMPACT

• ARCB ensures electrical and human safety by combining MCB and ELCB features: short circuit, overload, and earth leakage protection, along with pre-detection of electrical shock and short circuits
• It offers automatic recovery if the fault clears within 10 seconds; otherwise, it permanently trips the circuit

NEED OF ER&D

• ELCBs and MCBs protect against electric leakage in areas with electrical devices, safeguarding people and property
• ELCBs detect earth leakage after a brief electric shock; not before turning ON
• ELCB may trip seconds after an electric shock, while MCB only detects short-circuits or overcurrent when turned ON
• This may therefore cause damage to sensitive electrical equipment or wiring

ABOUT THE COMPANY

Company: LTTS
Sector: Industrial incl Construction
Automatic Recovery Circuit Breaker
Semiconductor sector Deep dive
**Semiconductors:** ER&D spend expected to reach $220-290B with focus on areas of packaging and new application specific developments

**SEMICONDUCTORS ER&D SPEND EXPECTED TO REACH $220-290B BY 2030 GROWING AT 9-10% CAGR...**

- $115B-$150B
- $220B - $290B
- +9-10%

**Sector's Business ER&D Spend ($B)**

**...WITH PACKAGING, ENERGY-EFFICIENCY & QUANTUM COMPUTING AS TOP 3 ER&D PRIORITIES...**

- Advanced Packaging and Chip Stacking: 67%
- Energy-Efficient and Low-Power Designs: 52%
- Semiconductors in Quantum Computing: 49%
- AI-led Innovation: 43%
- Growth of IoT and Edge Devices: 29%
- Heterogeneous Integration of Chips: 24%
- Silicon Photonics for Faster Data Transfer: 14%
- Environmental Sustainability in Manufacturing: 10%
- Neuromorphic Computing & Brain-Inspired Chips: 5%
- R&D in Memory & Storage Technologies: 5%

**% sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years**

**...ACCOMPANIED BY AN INCREASE IN SHARE OF DIGITAL ENGINEERING AS PART OF ER&D SPEND BY 18PP**

- 49%
- 67%

**% of sector's ER&D spend on digital engineering**

**Source:** BCG ER&D Survey 2023 n=281, Press Search, BCG Analysis
Two shifts will strategically impact Semiconductor ER&D spends

**AI IN CHIP DESIGN**

Use of AI to enhance chip design, testing, and manufacturing – to improve performance and cost-effectiveness

**Driven by:**
- Need to manage intricate semiconductor designs efficiently
- Need to manage vast data for insights and improvements
- Acceleration of product development, meeting performance demands and gaining a competitive advantage due to AI-driven innovation

---

**Innovation in Advanced Packaging & Chip stacking**

Innovative techniques for enclosing and connecting microchips, enhancing performance, energy efficiency, and device size reduction

**Driven by:**
- Requirement of enhancement of microchip speed and efficiency to boost overall device performance
- Demand for lower power consumption & longer battery life
- Demand for compact device design in various industries

Source: BCG Analysis
Rapid tech obsolescence & talent shortage are the two key concerns faced by ER&D players in the industry.

**CONCERNS HIGHLIGHTED BY ER&D LEADERS IN THE SECTOR**

- Rapid Technological Obsolescence: 76%
- Talent Shortage and Skill Gap: 71%
- Increasing Cybersecurity Threats: 67%
- Geo-Political Uncertainties: 62%
- Sustainability: 57%
- Shifting Consumer Preferences: 48%
- Interconnected Ecosystem Complexity: 43%
- Ethical and AI Bias: 29%
- Data Privacy Concerns: 24%
- Regulatory and Compliance Challenges: 24%

**KEY SKILLS REQUIRED BY ER&D PLAYERS IN THE SECTOR**

1. Micro-controller & Their Applications
2. Proficiency in Analog, Digital, and Mixed-Signal Circuit Design & VLSI
3. Proficiency in Electronic Design Automation (EDA) Tools

Source: BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
## INNOVATION BRIEF

The Micron® 2550 NVMe™ SSD delivers the latest, most advanced industry-first 232-layer NAND technology with outstanding PCIe® Gen4 performance and a superior user experience.

## NEED OF ER&D

- Enables fast, responsive applications and consumes extremely little power, dramatically helping extend compute time.
- The Micron 2550 SSD is designed to meet the rigorous requirements of both the Intel® Modern Standby Partner Platform Component List and the Open Labs’ SSD test requirements of Intel’s Project Athena.
- Product projected to deliver hundreds of millions of revenue for Micron.

## DESCRIPTION OF SOLUTION

- **The Micron 2550 SSD** is built with Micron’s industry-leading 232-layer NAND.
- This leading-technology NAND offers **100% higher write bandwidth and more than 75% higher read bandwidth per die than our prior generation** and is the world’s first six-plane production TLC.
- This new firmware is optimized for the needs of client devices with features like Predictive Cache Optimization & Modern Standby using Host Memory (HMB) technology.

## IMPACT

- The Micron 2550 SSD enables faster, more responsive applications in mainstream PC platforms, including gaming, consumer, and business client devices.
- It enables longer battery life on PC devices and allows to quickly wake up from low-power sleep to active working modes.
- The SSD performance surpasses competitors’ in PCMark® 10 benchmark scores.
Micron | 232-layer NAND SSD Chip
Software sector Deep dive
Software: Continuous innovation in software space will leverage new AI breakthroughs; Focus on cloud and cyber security expected to take ER&D spends to $370-500B by 2030

SOFTWARE ER&D SPEND EXPECTED TO REACH $370-500B+ BY 2030 GROWING AT ~12-13% CAGR...

% sector respondents who selected the topic as one of top 3 ER&D priority in coming 5-10 years

*Source: BCG ER&D Survey 2023 n=281, Press Search, BCG Analysis*
Four major trends will strategically increase software ER&D spends

**PLATFORM TOSUPER PLATFORMS**
- Strong ecosystems drive sizeable engineering development work from vendors and partners (developers) as the super platforms grow (AWS, Azure etc.)
- Platforms leverage advantage by expanding marketplaces through ER&D to accommodate more 3rd party solutions

**INTEGRATION OF ADVANCED AI/ML INTO ENTERPRISE SOFTWARE SUITE**
- Advances in Enterprise software focusing on sector specific data needs
- Enterprise infrastructure software will grow significantly over next few years, with fastest growth projected in AI Platforms
- Potential to increase automation as NLP and other AI driven outcomes can maximize productivity gains

**HUMAN-MACHINE INTERACTION AT SCALE**
- High growth for AR, VR, MR over coming years
- Abundant internet Bandwidth capabilities & enhanced hardware (Compute and sensor advances) to drive continued adoption of HMI at scale

**CONTINUED FOCUS ON CYBERSECURITY**
- Rising cyberattacks demand stronger software security measures
- Growing reliance on software intensifies the need to protect critical systems and data.
- Stringent regulations

Source: Global AR & MR Market, 2021-2026, Mordor Intelligence; Global Virtual Reality Market, 2016-2028, Grand View Research; BCG Analysis
Key concern in the industry is talent shortage and skill-gaps.

### Key Skills Required by ER&D Players in the Sector

- **Software Development Methodologies**
- **One Programming Language (Java, C++, Python, etc.)**
- **Protocols (OAuth etc.), and Security Testing**
- **AI/ML and Digital Technologies**
- **Data Analysis using tools like Python, R, or SQL.**
- **Product Documentation and Data Management Concepts**

### Concerns Highlighted by ER&D Leaders in the Sector

- **Talent Shortage and Skill Gap**: 79%
- **Data Privacy Concerns**: 68%
- **Sustainability**: 66%
- **Increasing Cybersecurity Threats**: 57%
- **Rapid Technological Obsolescence**: 53%
- **Geo-Political Uncertainties**: 40%
- **Ethical and AI Bias**: 38%
- **Interconnected Ecosystem Complexity**: 37%
- **Shifting Consumer Preferences**: 35%
- **Regulatory and Compliance Challenges**: 12%

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis

Multiple choices permitted per respondent. % shows the percentage of experts within a class that determined the choice as a future challenge.
Carrier | Healthy Buildings

ABOUT THE COMPANY

Company: Carrier
Sector: Software

INNOVATION BRIEF

Carrier.AI is delivering sustainable solutions to maximize energy efficiency, optimize operating & maintenance costs, ensure unparalleled asset uptime and occupant comfort for our Commercial buildings, residential and transport refrigeration customers.

NEED OF ER&D

- Carrier.AI invests and benefits from cutting edge Research and Innovation in scientific approaches to Model driven AI, Machine learning, Digital Twins, Digital Thread, matured IIOT infrastructure coupled with unmatched product expertise.
- HVAC Assets contribute to 40% of commercial buildings energy consumption.

DESCRIPTION OF SOLUTION

- Carrier’s Unique Advantages - Domain Expertise, Equipment & Building Models, Service Knowledge base, Install Base Telemetry.

IMPACT

- Customer Outcomes - Sustainability (Energy, Carbon Reduction, GWP, etc.), Occupant Comfort (Predict Comfort Loss), Equipment Uptime, Compliance, Performance Assessments & Benchmarks.
- Service Benefits - Remote Monitoring & Services, CBM & Technician Productivity, Modernization & Repair Recommendations, Predict Parts Replacement, Warranty Cost Reduction, Knowledge base.
**ABOUT THE COMPANY**

- **Company:** Wipro
- **Sector:** Software

**NEED OF ER&D**

- Globally, customers need a low-cost and scalable solution in digital manufacturing, supply chain, manufacturing execution and sustainability.
- However, COTS platforms are very costly and global deployment takes years.
- MIQ addresses all these problem statements and can scale to 100 plants/unit in 100 days.

**INNOVATION BRIEF**

MIQ is a scalable platform with dynamic UI, configurable low-code. Features digital manufacturing, supply chain, execution, and sustainability platforms.

**DESCRIPTION OF SOLUTION**

- MIQ is **Cloud-agnostic** and uses latest tech; scales globally for 100+ plants, high performance with minimal setup.
- The platform can be configured and deployed quickly for any customer.
- MIQ scales 100 plants/business units in 100 days, crucial for global customers as in-house solutions take years to scale.

**IMPACT**

- Comprehensive solution for connected enterprises: digital manufacturing, supply chain, execution, and sustainability.
- Low-cost solution that saves millions of dollars on costly license fees.
- Highly scalable platform that improves deployment time by 90%.
- Cloud-agnostic, works on-premises too.
Wipro | Manufacturing Intelligent Quotient - LC/NC
Telecommunication sector Deep dive
Telecommunication: ER&D spend expected to grow at 10-11% CAGR to reach $130-160B by 2030, maintaining the high share of digital engineering in spends.

Semiconductors ER&D spend expected to reach $220-290B by 2030 growing at ~10-11% CAGR...

...with Edge, Cloud, SDN, 5G & 6G as top ER&D priorities...

...accompanied by an increase in sector's digital engineering spend as share of ER&D spend.

Source: BCG ER&D Survey 2023 n=281, Press Search, BCG Analysis
Three trends will drive ER&D in Telecom sector

HYPERCONNECTIVITY

No constraints on the data rate, coverage, and computing newer technologies

Driven by:
- Development of 6G for low latency network
- ER&D players are focusing on the following emerging technologies for 6G - blockchain, quantum communication, energy harvesting & frequency bands
- IoT solutions to increase connectivity & productivity

ODA & VIRTUALIZATION

Openness & virtualization will increase speed to market of new software, increasing vendor options & flexibility

Driven by:
- Open API market growing at over 20% CAGR, Open Digital Architecture (ODA) has 30+ signatories from telecom industry allowing for plug-&-play deployments
- Move towards xRAN (ORAN & vRAN); vRAN to grow at ~19% CAGR b/w 2020 & 2030; ~$6.4Bn in 2030
- 37% reduced costs b/w traditional RAN & vRAN; 23% b/w C-RAN and vRAN

MOVE FROM “TELCO TO TECHCO”

Telcos moving towards providing Cloud/ICT solutions

Driven by:
- Increasing partnerships of Telcos with Hyperscalers
- Growth of Network-as-a-Service at over 30% CAGR b/w 2022 & 2025

Source: Press Search; BCG Analysis
As new technologies come up with development of 6G, focus on cloud offerings, etc. – talent shortage & skill-gap coming up as key issue in ER&D of telecom sector

**Talent Shortage and Skill Gap**

<table>
<thead>
<tr>
<th>Concern Highlighted by ER&amp;D Leaders in the Sector</th>
<th>% of Total Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talent Shortage and Skill Gap</td>
<td>67</td>
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<tr>
<td>Rapid Technological Obsolescence</td>
<td>57</td>
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<td>Data Privacy Concerns</td>
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<td>29</td>
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<tr>
<td>Ethical and AI Bias</td>
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</tbody>
</table>

Multiple choices permitted per respondent. % shows the percentage of experts within a class that determined the choice as a future challenge.

Source: CapitalIQ, BCG ER&D Survey 2023 n=281; Press Search; BCG Analysis
Capgemini | AI native sustainable network for 5G and beyond

ABOUT THE COMPANY
Company: Capgemini
Sector: Telecommunications

INNOVATION BRIEF
Capgemini 5G Intelli-RAN framework is based on O-RAN architecture and supports 3GPP Release-16/17. Intelligent resource allocation mechanism is supported in RAN to help in optimizing the power consumption of RAN leading to energy savings.

NEED OF ER&D
- Per GSMA, network accounts for 90% of energy use for operator, with RAN representing >80% of this
- Capgemini 5G Intelli-RAN framework provides SW based approach aided by ML techniques to reduce power consumption in 5G RAN leading to energy savings from network

DESCRIPTION OF SOLUTION
- Capgemini has taken SW based approach with 5G Intelli-RAN CU/DU framework having inbuilt “Resource Monitor (RM)” module that can dynamically monitor and ensure efficient allocation of air-interface and compute resources
- RM based on cell/UE/slice KPIs and interference measurements, ensures efficient allocation of resource blocks adapting to the radio conditions, that in turn helps in improving power use

IMPACT
- Capgemini 5G Intelli-RAN framework has demonstrated that with dynamic monitoring of node KPIs and radio conditions and efficient scheduling of radio resources or cores, ~10% power saving can be achieved within node itself
- The framework is also highly optimized with respect to capacity/throughput supported per core leading to ~30% higher capacity that can be supported within same compute node
Capgemini 5G Intelli-RAN Framework has inbuilt SW functionality that helps in optimizing the radio resources and compute resources that in turn leads to energy saving of the node, and overall network. The savings in order of ~10% for typical Enterprise/Private 5G deployment.

The Intelli-RAN Framework is based on O-RAN based architecture and support both PNF based nodes (like small-cells running on embedded SOC) or CNF based nodes (running on COTS HW) deployments.

The “Resource Monitor” module of the RAN runs in inner-most loop and handles the optimizations without an external interface. The 5G Intelli-RAN Framework also supports E2 and O1 interfaces to be able to leverage benefits with xApps/rApps that can be deployed in network for energy saving or other use-cases.

Few details of the Intelli-RAN Framework are shown where the compute resources, radio resources and resource allocation is handled dynamically leading to energy saving and improved user experience.
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Boston Consulting Group partners with leaders in business and society to tackle their most important challenges and capture their greatest opportunities. BCG was the pioneer in business strategy when it was founded in 1963. Today, we work closely with clients to embrace a transformational approach aimed at benefiting all stakeholders—empowering organizations to grow, build sustainable competitive advantage, and drive positive societal impact.

Our diverse, global teams bring deep industry and functional expertise and a range of perspectives that question the status quo and spark change. BCG delivers solutions through leading-edge management consulting, technology and design, and corporate and digital ventures. We work in a uniquely collaborative model across the firm and throughout all levels of the client organization, fuelled by the goal of helping our clients thrive and enabling them to make the world a better place.

The National Association of Software and Services Companies (NASSCOM) is the premier trade body and chamber of commerce of the Tech industry in India and comprises over 3000-member companies. Our membership spans across the entire spectrum of the industry from startups to multinationals and from products to services, Global Capability Centres to Engineering firms. Guided by India’s vision to become a leading digital economy globally, NASSCOM focuses on accelerating the pace of transformation of the industry to emerge as the preferred enablers for global digital transformation. Our strategic imperatives are to reskill and upskill India’s IT workforce to ensure that talent is future-ready in terms of new-age skills, strengthen the innovation quotient across industry verticals, create new market opportunities - both international and domestic, drive policy advocacy to advance innovation and ease of doing business, and build the industry narrative with focus on Talent, Trust and Innovation. And, in everything we do, we will continue to champion the need for diversity and equal opportunity.