B 3 STATUS AND DEVELOPMENT PROSPECTS OF ICT IN GERMANY

Information and communication technologies (ICT) are of central importance for the innovation system and social and economic development of the Federal Republic of Germany. The ICT industry and its associated services sectors are a cornerstone of the German economy and are also closely interlinked with other industry sectors. The market volume of Germany's ICT industry currently amounts to EUR 126 billion and continues to grow further.[371] The ICT sector is one of the most important sectors of the German economy. However, due to its heterogeneous structure, it is less visible than other core sectors of the economy.[372] A high proportion of professionals working in ICT companies are highly qualified. The ICT industry is very research-intensive and is characterised by particularly high innovation dynamics.

ICT as an important general purpose technology

Even more important, though, are the indirect effects of the ICT industry and ICT technologies on other sectors of the economy. ICT has all the characteristics of a general purpose technology (GPT, cf. Box 12) and therefore gains particular relevance.

Important key areas of the German economy critically depend on the latest applications of ICT technologies. ICT facilitate the development of new products and services and new organisational forms and are thus essential for safeguarding Germany's competitiveness.[373] Examples include:

- Future production systems: The process of digitalisation dramatically changes organisational structures and production chains. The application of information technology will have a sustainable impact on mechanical engineering, automation technology and also automotive manufacturing in Germany.
- Future mobility: An ever-increasing proportion of vehicle-related value added is attributable to information technology and electronics. The optimisation of transport systems and traffic flows increasingly depends on ICT and networking.
- Future energy system: Germany's Energy Transition relies on the use of the latest ICT and complex organisational models such as smart grids or green ICT.
- Innovative medical systems: The combination of bioinformatics, genetic engineering and medicine is sustainably changing therapy methods and medical care systems (cf. Chapter B 1).
- Trade, distribution and logistics: Large segments of the service economy are significantly influenced by the latest ICT (e.g. e-commerce, customer information systems, etc.).

The dynamics of innovation in these areas of application crucially depends on a close interaction between users, ICT manufacturers and specialist ICT service companies.[374] All of these parties are required to conduct R&D projects in a cooperative manner. Especially in the area of digital technologies, the concept of an interlinked "open innovation" is widely accepted. In fact, a close vertical collaboration between ICT suppliers and ICT users is a key requirement for success. In addition to vertical information externalities, there are strong horizontal spillover effects between an industry's early users of the latest

General purpose technologies (GPT) BOX 12

Economic literature stresses the importance of general purpose technologies (GPT) for economic growth, productivity and employment.[375] These include cross-cutting technologies with a very high productivity effect on a variety of economic sectors. General purpose technologies have four common characteristics:

1. They can be used productively in a variety of applications.
2. Prices and performance features of the technology change greatly over time.
3. General purpose technologies facilitate subsequent innovations for numerous products, processes and business models.
4. There are strong correlations with other, complementary technologies and subsequent developments.

TAB 09 **Classification of ICT sector according to European Information Technology Observatory (EITO)**

ICT sector according to EITO classification	
	IT services
	Software
	Telecommunication services
	IT hardware
	Telecommunication equipment

Source: own depiction based on EITO (2013).

information technologies and companies that learn from the experience gained by these early adopters. These companies are further improving their ICT systems and adapting them to their organisational models, respectively.

Germany's capacity for innovation crucially depends on the dynamic organisational skills in the use of the latest ICT. The central questions are as follows: What are the structural conditions and what are the policy measures required for ensuring that key areas of the German economy are further expanding their competitive advantages through the early and effective use of new information and communication technologies? Will it suffice to largely rely on ICT technologies and products developed abroad? Or will it be important for Germany to have its own strong ICT production sector and associated ICT service providers? In the view of the Expert Commission, the importance of spillover effects and geographic proximity in the innovation process calls for a highly developed national ICT provider structure at least in key areas. This will be explained in more detail below.

Strong impact of ICT on growth and productivity

Given the special characteristics of general purpose technologies as described above, investments in the development and use of digital technologies have a strong influence on growth and productivity. Numerous recent studies have confirmed the effects of ICT investments on the productivity of individual sectors and on the national economy.[376] Particularly the high productivity growth in the United States between 1995 and 2005 has thus been attributed to an increased use of the latest I&C technologies.[377] This correlation has been documented not only in economic studies, but also in numerous productivity analyses at sectoral and company levels.[378] These studies have been reproduced in many other countries and have demonstrated the strong impact of various ICT user profiles on a country's competitiveness. Especially the productivity gap between the United States and Europe has been explained on the grounds of a higher intensity of ICT use in the United States.[379] Within the framework of the EU KLEMS Growth and Productivity Accounts, similar studies on productivity differences within Europe have been conducted since 2007.[380] These studies – as well as those conducted by the OECD – show that Germany's growth in labour productivity was relatively low between 2000 and 2009 and that ICT's effect on Germany's labour productivity is relatively low when compared with other countries.

Corresponding studies on the productivity effects of ICT investments in Germany are conducted at regular intervals.[381] The monitoring report of the BMWi shows that 22 percent of overall economic gains in labour productivity in Germany between 1995 and 2009 were attributable to investments in ICT.[382] Productivity effects were particularly high for business services and retail. ICT have a strong impact on individual sectors of the German economy; albeit the fact that their cross-sectoral impact on the overall economy is less pronounced than it is in other countries.

The structure of Germany's ICT industry

To analyse the structure and the international competitiveness of Germany's ICT industry, one needs to closely examine individual segments and their respective strengths and weaknesses. "ICT industry" or "ICT sector" is used as an umbrella term that includes both production sectors and service sectors. There are clear structural differences between the individual segments. While some of the economic sectors are dominated by large corporations and foreign enterprises, others tend to be characterised by medium-sized and domestic enterprises. The Federal Association for Information Technology, Telecommunications and New Media (BITKOM) recorded a market volume of EUR 126 billion for the ICT industry for the year 2012. Based on a broader classification of the ICT industry, the Federal Statistical Office and the BMWi recorded an annual turnover of EUR 222 billion in their Digital Economy monitoring report.[383] Based on the BMWi's classification, the ICT sector is one of the three most important sectors of the German economy. When measured in terms of revenue and employment, the ICT industry even outperforms mechanical engineering, the chemical industry and electrical engineering.[384]

Yet, despite its size, the ICT sector is less visible than other industries, which is also due to the heterogeneous structure of ICT companies. Germany's ICT industry is characterised by the following features:

- The ICT industry comprises both productive sectors and service sectors, with each having very different supply structures and development prospects.
- Several segments of the ICT goods production are exposed to stark international competition that is often characterised by high pricing pressure. As a result, German suppliers have reduced their capacities considerably over recent years.
- ICT services tend to have a higher development potential, but again there are significant differences between telecommunications service providers and IT service providers.
- Large parts of the ICT industry are characterised by fluid structures and entrepreneurship (e.g. software and internet companies), and their interests may differ significantly from those of large established companies.

Based on the development in the period 2000 – 2012, the following analysis outlines the areas in which structural deficits of the ICT industry have to be overcome in Germany, as well as potential starting points for promising future developments. A distinction is made between the following industry segments:
- IT services and software,
- telecommunications services,
- IT hardware, and
- telecommunications equipment.

Developments in the IT services and software segment

The market for information technology services and software continues to grow strongly in all countries and displays high innovation dynamics. Also in Germany, the market volume of IT services and software has increased significantly since 2000, reaching a value of EUR 52 billion in 2012.[385] The expansion of the IT services sector remained largely unaffected by the financial crisis. Between 2008 and 2011, the number of employees in the IT services sector increased by 115,000 to a total of 540,000.[386] This market segment offers the highest potential for the further development of the ICT industry in Germany. However, there are also structural deficits with regard to the growth and internationalisation of German IT service providers and software vendors. Many of the businesses are still dominated by SME structures and have only a limited international focus.[387] These companies largely focus their business on the German market, or mostly on other European countries in those cases where they do operate internationally.

Developments in the telecommunications services segment

Quite a different picture can be observed in the field of telecommunications services – a market segment that only grew by 3.5 percent between 2005 and 2012 (cf. Table 10).[388] It is important to distinguish between different groups of countries and market segments. While strong growth could be observed in telecommunications services in the emerging economies, the highly developed countries tended to stagnate. At the same time, landline-related services have been increasingly replaced by mobile services. In the highly developed countries such as the US, Japan,

the United Kingdom and France, this has led to the fact that major telecommunications service providers lost in added value as a result of deregulation and substitution competition.[389] In spite of new enterprises and temporary growth among mobile service providers, the highly developed markets in this segment were still subjected to comprehensive restructuring processes. Also in Germany, the market volume of telecommunications services declined in the period 2005 – 2012. In addition, the introduction of process technologies and the associated increase in productivity have led to a serious reduction of labour. Between 2008 and 2012 employment in the field of telecommunications services in Germany was cut by 7 percent per annum to 86,400.

Developments in the telecommunications equipment segment

Even more clearly than in the services sector, Germany has lost ground in international competition in the telecommunications equipment segment. The world market for telecommunications equipment was characterised by high growth and high innovation dynamics overall. Between 2005 and 2012 the global market volume rose by 8.3 percent per annum, reaching a value of EUR 395 billion. Especially the emerging Asian economies displayed double-digit growth rates in this segment (e.g. China 18.1 percent, India 14.8 percent). The German market for telecommunications equipment, however, grew by only 3.5 percent per annum. With a volume of EUR 12.6 billion in 2012, it accounts for a mere 3.2 percent of the world market.

The production and development of telecommunication devices has increasingly shifted towards Asian countries. These are putting established manufacturers in highly developed countries under pressure through low costs. Especially the German communications engineering industry has been heavily affected by this. As a result, German device manufacturers and suppliers have been successively withdrawing from this market since 1995. Manufacturers of telecommunications technology equipment and facilities have therefore been exposed to comprehensive restructuring processes and substantial job cuts. Up until the 1990s, German companies such as Siemens AG or Robert Bosch GmbH had been technological leaders in this field. However, in the course of digitalisation, these companies lost their leading position with regard to the latest generations of telecommunications technology. Between 2000 and 2012, Germany recorded significant reductions in value added and employment. Today, the telecommunications equipment segment employs no more than 45,800 people.

Developments in the IT hardware segment

The market for IT hardware was globally characterised by particularly high innovation dynamics and a pronounced trend to relocate production sites. Overall, the world market for IT hardware grew at an annual rate of 4.2 percent between 2005 and 2012, reaching a volume of EUR 360 billion. There were pronounced differences between the highly developed countries and the emerging economies. The market for IT hardware grew by 2.1 percent per annum in the United States, and by 1.6 percent in Japan. The EU market, however, experienced a downturn of 3.9 percent per annum.[390] In contrast, the BRIC countries recorded an average annual growth of 16.9 percent in the IT hardware market.

The IT hardware market was characterised by short product cycles in conjunction with sharp price cuts, whereby the world market was increasingly dominated by Asian companies. In Western Europe as a whole, and in Germany in particular, this resulted in major structural adjustments on the part of IT hardware producers. Initially, the market volume for IT hardware declined from EUR 28.9 billion in 2000 to EUR 21.3 billion in 2007. Exacerbated by the financial crisis, 2009 saw a further 42 percent decline to EUR 12.4 billion. In the subsequent years, Germany's IT hardware market failed to recover from the crisis. In nominal terms, today's market only achieves the level of the early 1990s (in 1991, the market volume for IT hardware amounted to EUR 13.3 billion). That said, IT hardware companies from Germany had never held a strong position on the world market. Thus the market comprised mainly niche suppliers, and even the remaining German manufacturers had largely abandoned their production since the onset of the financial crisis, if not earlier.[391] Foreign companies that had major, long-established production sites in Germany (e.g. IBM, HP, or Fujitsu), largely relocated their value creation in IT hardware to third countries. Between 2008 and 2012, employment in the field of IT hardware in Germany was cut by

TAB 10 **A comparison of growth rates for the ICT segments in the German market and the world market**

DATA DOWNLOAD

	Market volume in Germany 2012	World market volume 2012	Growth in Germany 2005–2012	Growth in world market 2005–2012	Share of German market in ICT world market
	(billion EUR)		(percent)		(percent)
IT services	**98,478**	**1,977,201**	**0.0**	**4.1**	**5.0**
IT services	34,799	493,539	3.6	3.2	7.1
Software	17,254	285,921	4.7	9.7	6.0
Telecommunication services	46,425	1,197,742	–3.3	3.5	3.9
IT hardware	**27,446**	**755,034**	**–1.0**	**6.2**	**3.6**
IT hardware	14,855	360,162	–3.9	4.2	4.1
Telecommunication equipment	12,591	394,872	3.5	8.3	3.2
Total ICT market	**125,924**	**2,732,236**	**–0.2**	**4.7**	**4.6**

Source: own calculations based on EITO (2013).

13 percent per annum, with currently only 21,000 people employed in this segment.

In the course of the last decade, the ICT industry as a whole experienced a significant shift from the production sectors towards the services sectors. The value chains were reconfigured, and Germany saw an expansion of customer-oriented service sectors in particular. In parallel, the upstream process stages were relocated to sites abroad or were increasingly concentrated on those few remaining specialist areas in Germany. The depletion of value creation processes in the field of production also led to major changes in the area of research and development in the ICT industry.

Analysis of R&D expenditure in the ICT industry

Across the globe, the ICT industry is one of the economic sectors with the highest R&D expenditure and the strongest dynamics. The leading multinational enterprises active in R&D increased their R&D expenditure in both absolute and relative terms (as measured in relation to revenue or value added, respectively). In the ICT industry, competition is shaped by very high R&D budgets and subsequent patent protection. An increasing number of the world's most important R&D companies come from the United States and from Asia. Most of them continuously increased their R&D intensity, i.e. their R&D expenditure as a percentage of turnover, in the period 2000 to 2012.[392] However, this does not only apply

to manufacturers of computers, semiconductors, and telecommunications equipment – sectors which have always been R&D-intensive. Software companies, IT service providers and internet companies are investing an increasing proportion of their revenue in R&D. In the services sectors, R&D expenditure is thus becoming more and more important relative to hardware development.

Germany's ICT industry only partially kept up with these international trends towards a strong increase in R&D investment and a growing R&D intensity among ICT service providers. In terms of R&D investment, Germany did not step up its efforts. Furthermore, the German ICT service providers did not develop as dynamically as comparable companies in other world regions. In Germany, R&D expenditure is still focussed on manufacturing companies – despite the fact that the remaining manufacturing companies have gradually lost importance. Cuts in production and employment frequently went hand in hand with a depletion of the corresponding domestic R&D.

R&D expenditure was significantly reduced in the area of telecommunications equipment in Germany between 2001 and 2011. With an internal R&D expenditure of EUR 1.1 billion, German companies can barely keep up with today's leading foreign suppliers. For instance, in 2011, Cisco was the only company to have an R&D budget of EUR 4.2 billion. Ten years ago, German telecom equipment manufacturers expended EUR 2.4 billion on R&D. It could be argued that even in 2001 this budget was too small to cope with the dynamic changes in terms of digitalisation and mobile communications. Since then, R&D expenditure has been reduced in several stages and companies started preparing their withdrawal from those business segments with the stiffest competition.

The IT hardware segment underwent a similar development: in 2011, Germany invested a mere EUR 600 million in R&D in this segment. R&D expenditure remained largely unchanged over the last ten years in Germany and focussed on a small number of specialist suppliers. Within the same period, the large multinational IT corporations continuously increased their R&D investments, and only few of them still maintain development activities in Germany.

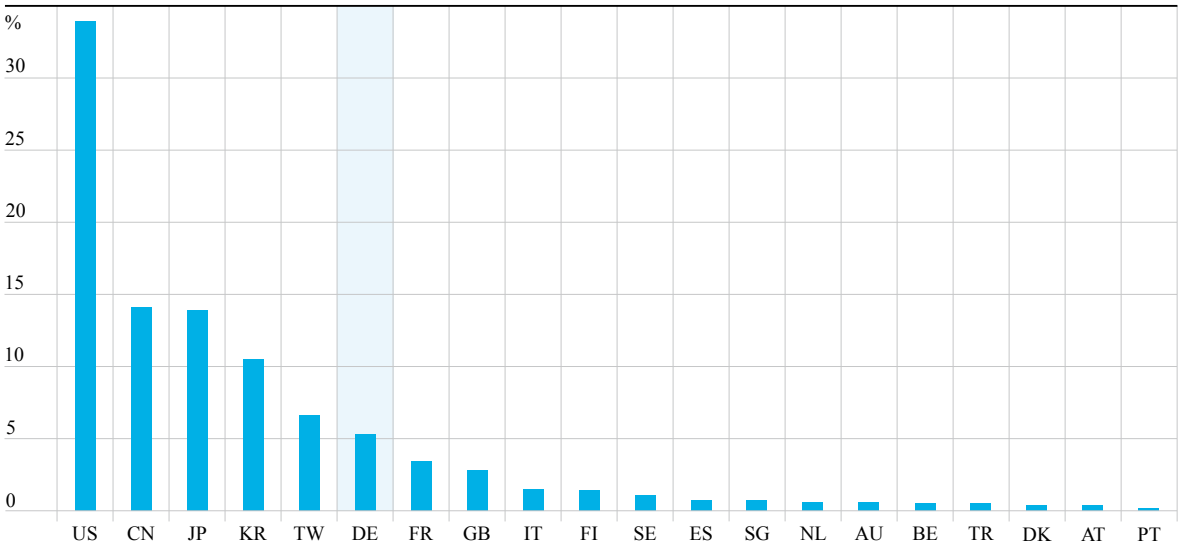
Domestic enterprises on their part have been transferring their R&D efforts to other fields. For several years now, R&D in the field of data processing and peripheral equipment account for only 1.5 percent of the German economy's R&D expenditure. While IT-related R&D efforts are also required in other industries, these largely focus on ensuring competitiveness in the respective user industries, e.g. in automotive and mechanical engineering. IT innovations are mainly utilised in individual industries and companies but do not have the same broad effect as in other countries. Thus, Germany is not reaping the potential benefits of ICT as a general purpose technology that can penetrate broad application areas and facilitate the creation of new industries.

While an expansion of R&D activities could be observed in the service-related segments of Germany's ICT industry, the structural change towards service-related R&D is less dynamic than in other countries. On a more positive note, Germany at least increased its R&D expenditure in the field of ICT services. R&D expenditure in the field of IT services thus increased over the last decade, reaching a value of EUR 2.3 billion in 2011 (2001 reference value: EUR 1 billion). This is complemented by the telecom service providers' R&D expenditure, which amounted to EUR 570 million in 2011 (2001 reference value: EUR 769 million). Yet, these R&D efforts should only be assessed in relation to other countries' R&D investments and innovation strategies. Numerous countries systematically expanded their R&D investments in the ICT sector, thereby placing stronger emphasis on service-related innovations and new business models.

Overall, the ICT industry as an innovation driver plays a rather moderate role in Germany. Due to the lack of major players, Germany's R&D efforts do by no means reach the level that is typically reached by other countries. An analysis of the global distribution of R&D capacities confirms that Germany plays only a subordinate role in the ICT sector.[393] 33 percent of global R&D expenditure in the ICT sector is attributable to the United States, followed by China and Japan at 14 percent each, and Korea at 10.5 percent. Germany ranks only sixth just after Taiwan (cf. Figure 30).

FIG 30 **The leading countries' share in global R&D expenditure in the ICT sector 2011** (figures in percent)

DATA DOWNLOAD



Source: Gehrke et al. (2014), calculations and NIW estimate based on OECD (ANBERD, BERD), Eurostat, complemented by national sources.

Analysis of patent applications in the field of ICT

Patents and other forms of intellectual property are playing an increasingly important role especially in ICT markets. Successful innovations strongly depend on patent protection and on legal access opportunities (freedom to operate). In the 1990s, in the period 2002–2008 and the years 2009–2012, the global number of patent applications in the ICT sector increased annually by double-digit percentages. The high technology list[394] distinguishes between six technological fields directly related to ICT. In the period 1991–2011, the communication technologies segment displayed the most dynamic development, followed by computer technology, radio and television technologies and electronics.

Table 11 shows the change in transnational patent applications between the periods 1999–2001 and 2009–2011. In the area of computer technology, the number of transnational patent applications increased from 20,346 to 26,550 in the leading countries. Ten years ago, Germany was still ranked third in this field. However, in the course of the last decade, Germany's share decreased from 10.3 percent to 6 percent. China gained considerable ground in computer technology patent applications and is now in third place and thus in front of Germany.

The telecommunications sector developed even more dynamically, with an increase in patent applications from 33,247 to 51,964. Ten years ago, Germany held a 15 percent share in transnational patent applications and thus ranked in third place, just behind Japan and at a considerable distance behind the United States – the undisputed leader in this field. Over the last decade, however, China managed to advance in the ranking, moving from former ninth place to the top of the list, even overtaking the United States. With a share of 7.3 percent, Germany now occupies the fifth position behind Japan and Korea.[395]

A study conducted in the context of the High-Tech Strategy (HTS) identified those fields of ICT that are highly relevant for the Federal Government's requirement areas as defined by the HTS.[396] The respective study shows that Germany is poorly positioned with regard to the majority of ICT fields, and that Germany displays an extremely unfavourable specialisation profile. This applies especially to displays, static memories, software, computers, and telecommunications.

Distribution of transnational patent applications in the field of computer and telecommunication in various countries

TAB 11

DATA DOWNLOAD

	Transnational patent applications in the years 1999–2001			Transnational patent applications in the years 2009–2011		
		Number	Share in %		Number	Share in %
Computer						
	USA	9,202	45.2	USA	13,948	52.5
	Japan	5,419	26.6	Japan	5,021	18.9
	Germany	2,105	10.3	China	2,216	8.3
	France	1,176	5.8	Germany	1,586	6.0
	Great Britain	1,147	5.6	Korea	1,299	4.9
	Korea	628	3.1	France	1,132	4.3
	Sweden	285	1.4	Great Britain	824	3.1
	Switzerland	254	1.2	Sweden	311	1.2
	China	130	0.6	Switzerland	213	0.8
	Total	**20,346**	**100.0**	**Total**	**26,550**	**100.0**
Telecommunications						
	USA	14,715	44.3	China	15,791	30.4
	Japan	5,670	17.1	USA	11,947	23.0
	Germany	4,974	15.0	Japan	8,026	15.4
	France	2,284	6.9	Korea	5,262	10.1
	Great Britain	2,251	6.8	Germany	3,790	7.3
	Sweden	1,633	4.9	France	2,718	5.2
	Korea	1,052	3.2	Sweden	2,185	4.2
	Switzerland	390	1.2	Great Britain	1,967	3.8
	China	278	0.8	Switzerland	278	0.5
	Total	**33,247**	**100.0**	**Total**	**51,964**	**100.0**

Source: own depiction based on Gehrke et al. (2014).

As long as the relevant intermediate products can be purchased on the world market at reasonable prices, this does not pose a problem as such. However, it can become a problem whenever strategic dependencies arise. There are only few fields of ICT in which Germany continues to be strong today. These include e.g. power electronics, machine control systems and radio navigation.[397]

Technology spillovers between producers and users of ICT

The performance of the German innovation system cannot be ascertained through an isolated analysis of the ICT industry alone. One of the crucial factors here is the production of knowledge and the adoption and development of ICT in user industries. More than in other countries, ICT-related R&D and corresponding patenting activities in Germany are concentrated on specific user industries. Thus, in 2010, 63 percent of ICT-related patent applications were attributable to sectors outside the ICT industry. Especially the automotive and supplier industries, mechanical engineering and the pharmaceutical industry increasingly patented inventions in the field of ICT. The relative importance of ICT patents has grown significantly in most user industries. In the period 2000–2010, the share of ICT patents in all patent applications rose from 8.8 to 10.1 percent in the automotive industry, from 3.3 to 6.8 percent in mechanical engineering, from 3.7 to 5.3 percent in the pharmaceutical industry and from 1.2 to 2.3 percent in the chemical industry.

Conversely, the strong links between the ICT industry and user industries are also demonstrated by the fact that ICT companies themselves increasingly file patents in the fields of mechanical engineering, chemistry and medical technology. In terms of their R&D activities, ICT companies increasingly accommodate for the needs of their industrial clients and acquire specialised skills in the clients' fields of expertise.[398]

The importance of standardisation and standard-setting consortia

System standards and interoperability agreements play an increasingly important role in ICT and the application thereof. Early participation in important standardisation committees and an active influence on such committees are crucial competitive factors in the ICT sector. More and more ICT standards are protected by patents, and these are of central importance to the enforcement of the relevant standards and the business success of the companies involved. What is more, innovations are often dependent on a large number of patents being held by different companies. The parties involved need to have access to all standard-essential patents in order to offer products that are compatible with the respective standards in all the relevant markets.

A recent study by the European Commission reveals that more than 1,500 ICT standards are protected by essential patents.[399] Typical examples here are patents on important standards such as MP3, UMTS or LTE. In recent years, patent disputes relating to standard-essential patents have become more frequent.

In the 1990s, and also at the beginning of the 21st century, German companies took an active part in the development and standardisation of essential patents. German research institutions and companies (among them Siemens AG, Robert Bosch GmbH, and T-Mobile Deutschland) played an important role in introducing telecommunications standards such as GSM and UMTS. As a result, Germany was regarded as an important technology development centre in

BOX 13

Patent litigation on standard-essential patents

Bei standard-essenziellen Patenten (standard essen Standard essential patents (SEPs) are patents protecting a technology that is essential for complying with a given industry standard. In principle, this makes it technically impossible to market a standards-compliant product without making use of the technology protected through the corresponding SEP.[400]

Many companies try to use their standard-essential patents to the detriment of their market competitors. In 2012, Google, for instance, used the standard-essential patent portfolio acquired through the acquisition of Motorola against Apple and even obtained temporary sales bans. A similar strategy was employed by the Chinese company Huawei against its domestic competitor ZTE.

Meanwhile, both patent litigation cases have been suspended before the regional courts of Mannheim and Düsseldorf, respectively. Today, almost every company in the mobile phone industry is involved in patent disputes – both as plaintiff and as defendant. The conditions under which holders of standard-essential patents may enforce an injunction against an infringing party are currently being examined with reference to European competition law.[401] Furthermore, academic institutions and competition authorities are presently engaged in a lively debate on the future viability of the FRAND licencing model.[402]

Germany has become the central location for patent disputes, which is partially owing to the fact that disputes can be fought out relatively quickly and inexpensively in Germany.[403] The Expert Commission notes with concern that the number of disputes in the field of SEPs has increased considerably over recent years.

Beyond this, it can also be observed that an ever increasing number of "patent trolls" is attempting to legally enforce patents – sometimes of questionable quality – with the aim of giving voice to their extensive licence claims. In this context it should be ensured that the new European patent system does not provide for strategic opportunities to expose supposed infringers to high cost pressure as a means of enforcing licence claims.[404]

this area up until 2004. Also thanks to these efforts, Europe was one of the main locations for the standardisation of communication technology.

However, the proportion of standard-essential patents filed by German companies has decreased significantly since 2004. Standardisation markets and standardisation centres experienced a shift towards Asia. In contrast to earlier years, European companies no longer exerted their influence on essential standards relating to the fourth generation of mobile communications. Instead, new market participants from Asia (e.g. Samsung, Huawei, as well as the Asian network providers) are increasingly playing a key role in the process of standard-setting, while at the same time investing heavily in R&D and new product generations.[405] In the course of these developments, stakeholders from Germany have lost their relevance as holders of standard-essential patents in recent years. Furthermore, they also significantly reduced their patent-related R&D activities or moved their R&D sites to locations abroad.

In addition to official standards organisations such as ISO, ETSI and ITU, standard consortia have also become relevant players in standard setting by defining important system standards – especially in the area of internet and software. Currently there are more than 450 of such ICT-related standard consortia worldwide.[406] A study on participation in standard consortia in the ICT sector shows that German companies were very active ten to 15 years ago. In recent years, however, the influence and presence of German companies has declined significantly. Especially with regard to new, promising standards such as the HTML 5 and the cloud standard, there is a danger that Germany will be excluded at these important junctures. Cloud computing, an area that is becoming ever more topical, is largely dominated by leading stakeholders and standard-setting consortia from the United States.

The Federal Government's R&D funding in the field of ICT

Under its ICT 2020 Programme, the Federal Government has been providing targeted funding to information and communication technologies since 2007.[407] The communication sector plays a central role within the Federal Government's High-Tech Strategy. Each year, the Federal Government hosts a top-level status conference on communication during its annual IT summit. While previous public support programmes focussed on promoting ICT as a key technology on the supply side, today's support programmes are designed more along the lines of key fields of ICT applications and key ICT systems. As a consequence, research funding is now largely focussed on application areas and industries in which Germany has proven strengths, and these strengths can even be further enhanced through the use of ICT. ICT applications are supported especially in the automotive and mobility industries, mechanical engineering and automation, healthcare and medical engineering, logistics and services, as well as energy and the environment.[408]

Given the complexity of these fields, it was necessary to develop new types of strategic funding tools. Previously, the Federal Government had largely relied on three types of ICT funding tools: lead innovations, technology alliances and service platforms. The promotion of lead innovations included the creation of innovation alliances on central aspects of ICT application, among them e.g. the Automotive Electronics Initiative, the Networked Intelligent Objects in Logistics Initiative, the Safe Mobility Through Communication Technologies Initiative, as well as ICT in the field of healthcare.[409]

In addition, vertical collaborative projects involving users, manufacturers and research institutes have been established within the framework of technology networks. In parallel, horizontal organisational alliances were funded, provided that these involved the collaboration of several companies in joint ICT research domains. Examples include projects such as standards for communication of the future, virtual technologies and real products, digital product memory, as well as ambient intelligence for autonomous networked systems.[410] The instrument of service platforms was characterised by a stronger focus on services and business models. Here, projects included topics such as ICT for services and the provision of services, as well as flexible modules for communication services.

Overall, the Federal Government invested EUR 3.2 billion in ICT within the period 2007 to 2011. Of this amount, EUR 1.74 billion was allocated to the institutional funding of science organisations, and

EUR 1.48 billion was allocated to ICT project funding. In contrast to other countries, the lion's share of funds was directed towards public research organisations.[411] Since 2012, R&D funding in the field of ICT has been continuously expanded even further. To assess the effectiveness of funding, it would be necessary to conduct an evaluation of strategic funding measures in order to find out which of the above support projects has succeeded in strengthening Germany's international competitiveness. While the topics supported stand out for their diversity and complexity, they are faced with a strong consolidation of R&D and value added in the German ICT industry.

The EU's R&D funding in the field of ICT

On the side of the EU, the promotion of ICT has played a prominent role across various phases of the Research Framework Programmes. ICT has been recognised as an important general purpose technology and as a means of overcoming the productivity gap between the United States and Europe. The European Union's ICT support measures are based on three objectives: fundamental and application-oriented research into ICT, application of ICT to increase productivity and competitiveness in industry, and creating solutions to major societal challenges (e.g. in the fields of healthcare, energy, mobility) through the development and use of ICT.

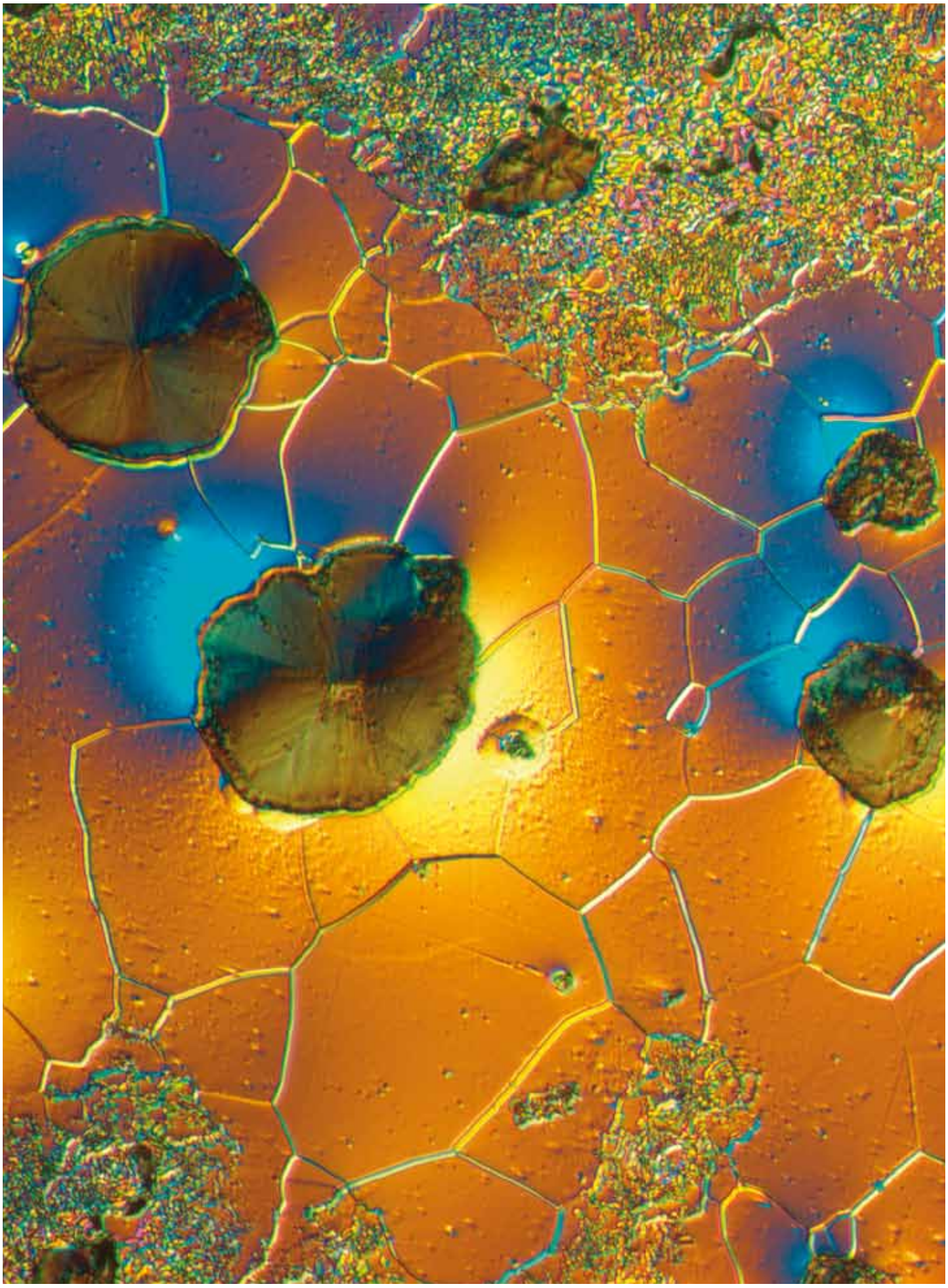
With a volume of EUR 9 billion, ICT support measurers constituted the largest budget item within the 7th Framework Programme. In the period 2007 to 2013 a total of EUR 1.5 billion was allocated to project participants in Germany, which equals 21 percent of the EU's ICT funding volume. German beneficiaries held a coordinating role in 20 percent of projects funded. Public research in Germany received 63 percent of EU funds, with 34.2 percent of this going to tertiary education institutions and 28.4 percent to non-university research organisations, while Germany's private sector was allocated 36 percent of EU funds.[412]

The follow-up programme, Horizon 2020, has a total budget of EUR 80 billion for the period 2014 to 2020. While the exact funding volume for ICT has not been published yet, it can be assumed that it will constitute a large part of the overall budget. Funding measures are strategically bundled within the Digital Agenda 2020. Furthermore, ICT plays a key role within the EU's Smart Specialisation (RIS3) strategy that aims to redesign the allocation of public funds and regional innovation initiatives.

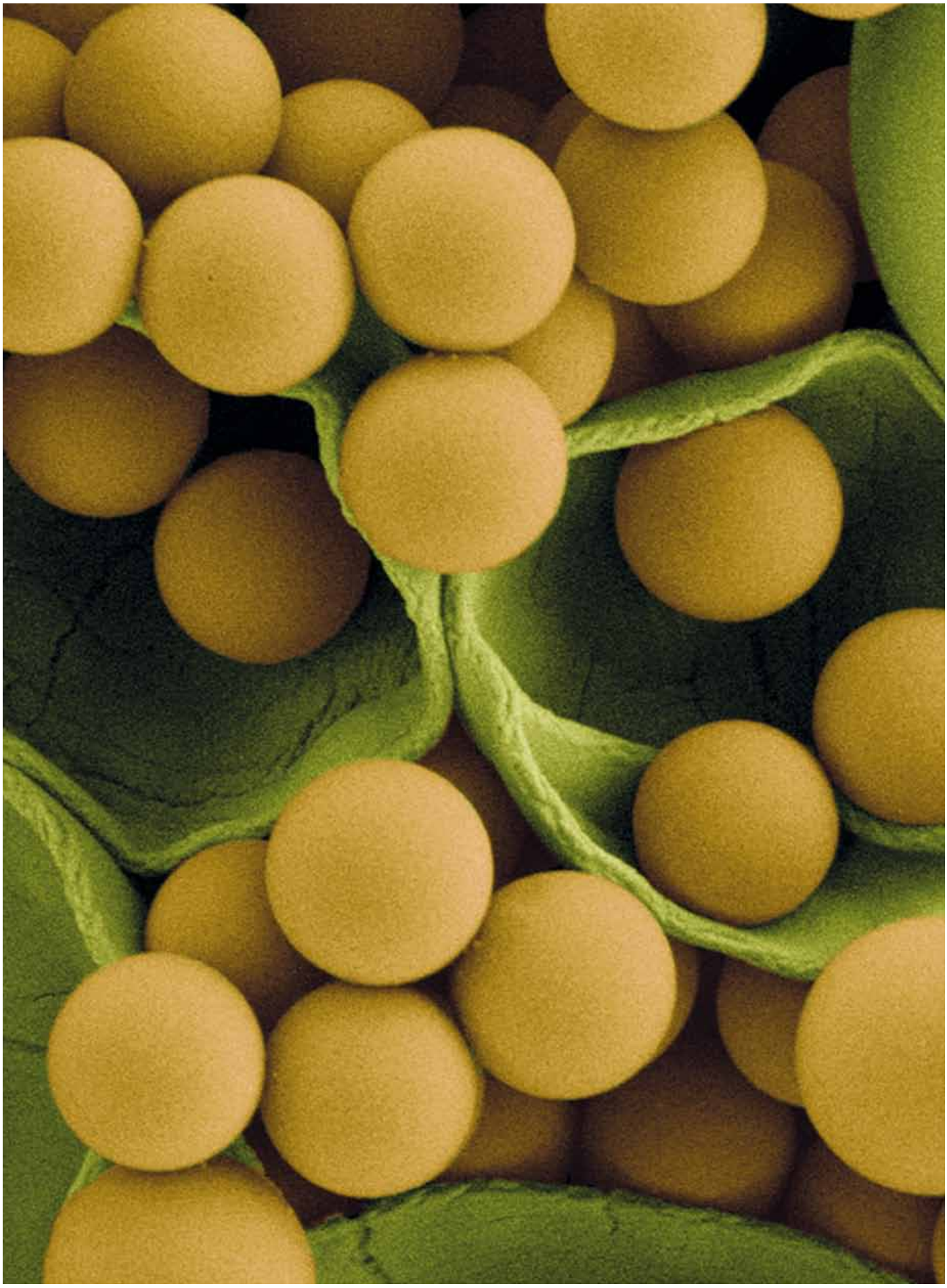
The following action areas have been specified within the Digital Agenda: creating a single market for the digital economy, enhancing interoperability and standards in the area of ICT, improving data security, facilitating high-speed internet access, enhancing digital literacy and inclusion, as well as applying ICT to address major societal challenges. Detailed objectives and concrete performance indicators have been defined for each of these action areas. The Smart Specialisation strategy focusses to a much greater extent on developing unique skills to be distributed across EU regions. The European regions are encouraged to make greater use of the potential of ICT applications and to identify specialisation advantages in specific niches in the adaptation of this technology. The development and implementation of an ICT-specific Smart Specialisation strategy is a particular challenge for Europe. The EU aims to secure value creation and employment in Europe through the development of unique ICT applications and regional competence clusters. However, the absence of strong industrial partners entails the risk that many regional solutions will merely represent reproductions of existing products and services. The Expert Commission is doubtful as to whether these initiatives will be able to substantially strengthen Europe's ICT industry.

Recommendations

High priority should be attached to the future development of ICT and its broad utilisation as a general purpose technology for business and social life. The Expert Commission welcomes the fact that the Federal Government attaches great importance to ICT, which has also been documented in the coalition agreement. The Digital Agenda for Germany as proposed in the coalition agreement defines guidelines for the development of the digital economy and infrastructure for enhanced digital education and research as well as the broad utilisation of ICT in the workplace and in social life.[413] While these objectives are a step in the right direction, the coalition agreement does not specify in detail how objectives are to be achieved and what constraints are to be



Reflected-light microscope with polarised light and differential interference contrast.



Coloured scanning electron microscope image.

overcome. With regard to the future course of this process, the Expert Commission would like to suggest the following recommendations.

The Digital Agenda for the period 2014 – 2017 is to be elaborated in consensus between businesses, social partners, civil society and academia.[414] When adopting and implementing the Digital Agenda for Germany, the following points should be taken into account. The use of resources and the attention of the public sector should be focussed on specific ICT applications that are highly relevant for the future economic and social development in Germany. These applications should also be closely linked with the Federal Government's requirement areas as specified in the HTS and the funding priorities within the EU's Horizon 2020 framework programme. With regard to defining the priority fields of ICT application, the Expert Commission endorses the recommendations made at the previous IT summits, as well as those made in a study on the application potentials of telecommunications.[415] Based on this, the most important topics include:

– Future production systems, digitalisation, and Industry 4.0;
– future mobility, automotive and new transport systems;
– innovative medical systems, healthcare and e-health;
– future energy system, smart grid and energy system optimisation;
– utilisation of ICT to optimise trade, distribution and logistics.

The structure of value chains should be analysed for each of these fields of application, and the most critical development stages and skills areas should be highlighted clearly. The smart utilisation and the development of new ICT services and business models should be at the core of Germany's future development in ICT. Support measures should strategically focus on those components and IT products that are particularly critical and require geographic proximity – and are thus essential for securing these fields of application.

Innovations in the field of ICT are being globally advanced by start-ups and international growth strategies of young ICT enterprises. With regard to entrepreneurship in ICT, Germany is less dynamic than many of its analogue countries, and only few German ICT businesses embark on ambitious international expansion strategies. Too many potential entrepreneurs relocate to other countries, and ICT companies with a high growth potential are often taken over by foreign companies at an early stage. Suitable instruments for the support of new enterprises and growth financing should be employed to ensure that strong German companies continue to be represented in the international ICT growth markets.

Business success in the field of ICT largely depends on system standards and standard essential patents. If Germany is to position itself in important fields of technology, it will have to actively participate in major standard setting consortia and standardisation organisations at an early stage. The coalition agreement includes only vague statements on a comprehensive standardisation strategy. The Expert Commission therefore strongly advocates strategic standard monitoring and an active and coordinated participation of German companies and research institutions in the most important international standardisation processes.

The digitalisation of production systems and value chains will bring about fundamental changes in the years to come. To address these developments, the Federal Government has launched its Project of the Future: Industry 4.0, a project that has also been highlighted in the coalition agreement. Due to its strong focus on the links between ICT, internet and production, Industry 4.0 can be considered a very important initiative. In the context of the Industry 4.0 project it should be ensured that system solutions have an international design and that Germany takes a decisive role in shaping international ICT standards for production and automation technologies. Governments in the United States, Japan and China have launched similar initiatives, albeit with a focus on cyber-physical systems. Parallel or concurrent developments should be avoided as early as possible.

Many experts consider cloud computing and new ICT architectures as the next revolution in ICT.[416] The decisive factor here is to identify both the leaders and the beneficiaries of cloud solutions. On the user's side, SMEs are potential beneficiaries as cloud technologies enable them to use IT technologies that were previously available to large companies only. Pilot

applications could be used to demonstrate practical suitability, as well as new applications and data security to users in SMEs in particular. On the supply side, measures should be taken to ensure that cloud computing infrastructures can be developed in Germany or at least at a European level. The market is currently dominated by large ICT corporations and IT providers from the United States. These companies exploit their advantages over European providers who are disadvantaged due to different national safety standards, data protection regulations and processes. Priority should be attached to creating a uniform legal framework for cloud computing. The current draft of the EU Regulation on data protection still includes a number of issues that limit the flexibility of European companies. The Federal Government should endeavour to ensure that a European standard for cloud security is created.[417]

To achieve a rapid diffusion of the latest ICT, a coordinated policy is needed between the Federal Government, the *Länder* governments and the communities in the area of broadband infrastructure. New applications in the fields of education, healthcare and e-government will only be able to unfold positive effects if they can be provided via broadband networks. When compared with other countries, Germany has yet to catch up in this regard. Germany is still characterised by high disparities across federal states and a pronounced gap between rural and urban regions.[418] The Federal Government intends to launch a programme for expanding high-speed internet accessibility by 2018. The Expert Commission welcomes this initiative. However, additional steps should be optimised along the lines of economic principles; full provision at any cost cannot be the goal here.[419]

In the area of e-government, Germany is currently in midfield when compared internationally. E-government makes an important contribution to the public accessibility and efficiency of public administration. E-procurement, i.e. the electronic tendering and awarding of procurement contracts, can play a central role in ensuring efficiency in the public procurement system. The Federal Government should attach the highest priority to promoting the use of ICT in government services. Efforts in this area would also generate positive effects on the demand side of the ICT industry.

The ICT support strategies of the EU and the Federal Government continue to show a lack of systematic evaluations that would ensure an efficient and effective allocation of funds. In this regard, it should also be assessed whether research funds allocated succeed in sustainably improving the competitiveness of the ICT industry in Germany and the EU.

Finally, R&D tax credits would ensure that especially research-intensive SMEs, which play an important role in ICT, can benefit from funding measures. The Expert Commission therefore reiterates its call for an immediate introduction of R&D tax credits.