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RESEARCH INFRASTRUCTURES

H2020-INFRAIA-2014-2015

INFRAIA-1-2014-2015 INTEGRATING AND OPENING EXISTING NATIONAL AND REGIONAL RESEARCH INFRASTRUCTURES OF EUROPEAN INTEREST

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LIST OF ACRONYMS AND ABBREVIATIONS

ATLAS	A Toroidal LHC ApparatuS
BWR	Boiling Water Reactor
CCC	Crystal Clear Collaboration
CERIMED	Centre Européen de Recherche en Imagerie Médicale
ClearPEM	Clear Positron Emission Mammography
CMS	Compact Muon Solenoid
EBIT	Earnings Before Interest, Taxes and Amortisation
EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortisation
EPS	Earnings per share
D&D	Design and Development
GEN II	Generation II reactor
GEN III	Generation III reactor
GEN IV	Generation IV reactor
ICT	Information and Communication Technologies
IP	Intellectual Property
LHC	Large Hadron Collider
NPP	Nuclear Power Plant
PET	Positron Emission Tomography
PWR	Pressurised Water Reactor
R&D	Research and Development
RAB	Report Acceptance Body
RDC	Research to Development to Consumer

Foreword

Nuclear physics brings many innovations for economy and society. Nuclear physics designates future directions in important areas such as energy, medicine, pharmacy, scientific instruments and many others. Innovative products, processes and inventions in this field arise thanks to the efforts of many scientists from different countries working in the field of basic and development research.

There is still much to be done in the field of nuclear physics innovation. Achieving effects in the form of new products, processes and inventions requires not only efforts to obtain results from the conducted research but also the skilfulness of their transfer to industry. The modern world expects scientists not only to solve problems in various areas of science but also to cooperate with the industry, which is supposed to result in innovations.

When preparing this report, we concluded that one should focus on the areas on which the socio-economic progress of the modern world depends. We have concluded that among the areas of the industries that challenge science there are areas such as nuclear energy and medicine. Of course, we realise that many other areas are important for the modern economy, but these two areas have a significant impact from the point of view of socio-economic needs.

In the report, we tried to identify future investment directions, enterprises of significant importance for progress in the field of new technologies and their financial capabilities, directions of development of technological innovations. We believe that the area that requires special attention in this case is nuclear energy. Taking into account social needs and the pace of an aging population, as well as the lifestyle, we see the essential nature of nuclear physics in the creation of medical innovations. Therefore, medicine is another important industry that requires researchers to engage in long-term research and development cooperation.

In the report, we have suggested the models of network cooperation between science and industry. In practical applications, the model of open innovation and the technological innovation model are of particular importance. These models should set standards and directions on how to include the activities of laboratories participating in ENSAR2 in creating innovative products and processes for the needs of the global economy. Our report contains recommendations for participants of the ENSAR2 project.

Global Investment in Nuclear industry to 2050

An estimated investment cost of USD 4.4 trillion (see Table 1) would be needed to reach the 930 GW of installed capacity under the *ETP 2015* 2DS by 2050. About 40% of these investments (USD 2.0 trillion) would be required in OECD member countries to extend lifetimes of existing plants, to replace retiring plants and to add new capacity. China, which accounts for one-third of capacity in 2050, would need to invest approximately a quarter of the overall investment cost, or just over USD 1 trillion in new nuclear capacity.[8]

Country/region	2012-20	2021-30	2031-40	2041-50	2010-50
United States	90	216	288	118	713
European Union	113	168	259	164	704
Other OECD	83	153	178	162	577
China	209	309	350	157	1 025
India	21	120	114	158	412
Middle East and Africa	18	70	82	133	303
Russia and former Soviet Union	96	94	176	182	548
Other developing Asia	14	68	40	31	153
Other Americas	12	5	3	6	25
World	656	1 210	1 493	1 115	4 473

Table1. Investment needs.

Source: Schneider M., Froggatt A.: The World Nuclear Industry. Paris. September 2017 [8]

Identification of companies, their strategies and finance ratings

The most important companies from the nuclear industry with their strategies and financial analyses are listed below. We believe that these companies are important from the point of view of building a science-industry network.

RWE

For 2016, Rheinisch-Westfälisches Elektrizitätswerk or RWE group published financial results with revenues falling 5.7 percent, while adjusted EBITDA fell by 23 percent. Net income finished in the red once again at –€5.7bn (–US$6.15bn) as the group booked €4.3bn (US$4.6bn) of impairments in its power portfolio, in addition to €1.8bn (US$1.94bn) for the nuclear energy fund 35 percent risk premium, and €0.8bn (US$0.86m) from mark-to-market of derivatives (valuing assets at quoted prices). Adjusted for this, net income fell by 30 percent to €777m (US$838m).

In line with 2015, the company has decided to pay no dividend for its common shares and €0.13 (US$0.14)/share on preferred shares. Net debt decreased by 10.8 percent, helped by the positive cash generated from the placement of Innogy shares through the spin-off.

RWE's share price peaked in January 2008 at €100 and stood at €18 per share by early July 2017, an 82-percent decline. However, RWE is clearly on its way to recovery as share value hit the bottom in December 2016 at €11.40

RWE's objective on nuclear provisions is to keep enough financial assets to cover its medium-and long-term obligations (nuclear, mining/lignite, and pensions) 100 percent for the next five years and 75 percent for the next ten years. Nuclear provisions will be recalculated like pension ones on a quarterly basis, where the movements will be registered on the Profit & Loss (P&L) statement.

Following the Innogy spin-off and the current financial structure of the company, with all the senior debt being transferred to Innogy, but still being liable for its long-term provisions, RWE can be seen as a financial portfolio with no debt, which has "volatile" cash flows from trading and generation, but where its financial investments and received dividends should allow both its provision levels and cash payments to be covered.

The important news came from 2017 guidance with top-line earnings expecting to have a flat to 5 percent increase, implying that the downward trend may be over and the strategy is finally paying off. Moreover, there is a strong net income improvement expected, implying a 25 to 62 percent increase in net profit. The group will reinstate a dividend payment of €0.50 (US$0.54) per common share in 2017. It seems as if the worst days are over and the separation strategy with the creation of Innogy as a growth driver is paying off.[9]

E.ON

In 2016, revenues fell by 11 percent, with adjusted operating profit and net income decreasing by 13 percent and 16 percent respectively. On a reported basis, the group booked a combined net income loss of €16bn (US$17.3bn), of which €8.4bn (US$9.1bn) is attributable to E.ON's shareholder, driven by close to €11bn (US$11.9bn) in impairment charges. The dividend proposed for 2016 is €0.21 (US$0.23)/share.

The equity attributable to E.ON shareholders finished in negative territory at -€1.05bn (-US$1.13bn), while the net debt of the group reached €26.3bn (US$28.4bn), confirming the firm's weak balance sheet. E.ON shares hit the bottom in November 2016 at just over €6 per share, down from an all-time high in January 2008 at €45.60 (–87 percent). At €8.31 per share as of early July 2017, the title has made up some lost territory.

Following its spin-off strategy, E.ON has achieved an improvement in exposure to market-driven earnings, as 63.3 percent of its operating profit now comes from regulated and semi-regulated assets. Energy networks had an 8 percent reduction in adjusted operating profit. The retail business (Customer Solutions) had relatively stable operating profit (+1 percent). The renewable division's operating profit improved by 10 percent.

German nuclear (Preussen Elektra)'s operating profit has been more resilient than expected as its operating profit decreased by 2 percent. However, profits should continue to deteriorate as production for the coming years is hedged at a lower price: 100 percent hedged for 2017 at €32/MW (US$34.5/MW), 94 percent in 2018 at €27/MW (US$29.1/MW), and 19 percent in 2019 at €25/MW (US$27/MW). At constant production levels, the coverage would imply a decrease in revenues of 13.5 percent for 2017, an additional 21.7 percent contraction in 2018, and a further 7.4 percent decrease in 2019.

But not all is so bleak on this front, as the transfer of the storage-related provisions to the nuclear waste fund would allow the company to stop interest payments on €7.8bn (US$8.4bn) of provisions from 1 January 2017, having a positive net income effect of €200–250m (US$216m– 270m) per year. Moreover, the change in the discounting

method for the remaining provisions would also reduce the accretion charges by €350m (US$377m). Hence, the combined financial effect from 2017 onwards is expected to be improved by roughly €400m (US$431m), partially offset by higher depreciation expenses.
Over the medium term, the company is targeting to reduce net debt, reduce its investment budget by 20 percent, could sell all of its remaining Uniper shares, divest additional assets, and perhaps pay a scrip dividend with newly issued shares. As for the objective expectations, Earnings per Share (EPS) have been lowered as they are now expected to be relatively flat. This downward revision is driven by the negative EPS-diluting effects on capital measures to pay the nuclear premium for the sovereign fund. A flat EPS is expected until 2019, meaning E.ON has turned into a no-growth story for the coming years.[9]

AREVA

For 2016, the company reported a net loss of €665m (US$717m), reduced from €2.04bn (US$2.2bn) in 2015, and €4.83bn (US$5.2bn) in 2014. Cash flows continue to be in negative territory, with a net cash flow from operations at –€621m (-US$661m). In recent years, the group had to revise downwards its expectations for the construction of third-generation EPR reactors, driving massive depreciations, added to constant delays on the EPRs at Olkiluoto in Finland, Flamanville in France, and Taishan in China. In addition, AREVA had to cope with a vast quality-control problem at its Creusot Forge site, where inspectors identified irregularities that have apparently lasted for decades.
AREVA's shares peaked in June 2008 at just under €80 per share and stood at below €4.50 in early July 2017 (–94 percent). The French government bailout announcements did not fundamentally change investors' opinions.
The group has been obliged to split in two to get the much-needed financing, with the nuclear reactor division (AREVA NP) being sold to EDF (51–75 percent) for a €2.5bn (US$2.7bn) price, with a possible earn-out of €350m (US$377m), if results meet expectations. AREVA SA will keep the fuel fabrication and spent fuel-reprocessing operations. On top of this, a €5bn (US$5.4bn) capital increase will be performed, whereby the French government will inject €4.5bn (US$4.9bn), potentially letting some international investors such as Japan Nuclear Fuel Limited (JNFL) and Mitsubishi Heavy Industries (MHI) get in with the remaining €500m (US$534m).[9]

EDF

Électricité de France (EDF) had a volatile year. In addition to multiple strategic decisions taken in 2016, the company suffered from the decreasing profitability on its nuclear assets due to a low-price environment. This added to increased competition in its two main markets (France and U.K.), which created not only erosion of its market share but also dwindling earnings and profitability.
EDF issued two different profit warnings in 2016. The negative impact from lower power prices had been accentuated by a reduced nuclear production, as the nuclear regulator (ASN) demanded additional tests on nuclear reactors affected by the AREVA manufacturing anomalies. Moreover, in 2016, EDF issued its final investment decision on the construction on the £19.6bn (US$25.4bn) EPR project in the U.K., which has been validated by the U.K. government, including Chinese investors (CGN and CNNC) in its capital structure. The group has also found an agreement on the purchase of AREVA NP for an agreed price of €2.5bn (US$2.7bn).
Driven by its financial difficulties, weak balance sheet, and multiple capital-intensive projects and ambitions, EDF has issued a €4bn (US$4.3bn) capital increase at €6.35 (US$6.85)/share, with 634.71m new shares created for this purpose. The subscription price has been set with a 34 percent discount to the closing level on 2 March 2017 and 29 percent on the theoretical value of the share ex-right, i.e. €8.92 (US$9.62)/share. The discount provided was required as the company needs to get €1bn (US$1.08bn) of fresh capital from private investors (representing 25 percent of the total objective, but targeting 15 percent of the shareholders). The French government participated with a €3bn (US$3.23bn) envelope (75 percent), but has an 85 percent stake in the company. As a result, the public stakeholder disposed 10 percent of its share rights at €0.40 (US$0.43)/right, implying a 40 percent discount on the ex-right values and creating a technical 8 percent decrease on the stock price. EDF's share price dropped 22 percent in the week following the launch of the capital increase on 7 March 2017. EDF shares plunged by 89 percent since they peaked in November 2007.
Moreover, the company substantially revised downwards its 2017 earnings objectives. As the company normally starts the year with its production fully hedged, it implies a lower hedging price, in addition to a lower nuclear production and increased competition in its main markets. The group expects a rebound in 2018 earnings, as forward prices increased across Europe at the end of 2016 and production is expected to return to normal levels.
The group's 2016 financial performance was heavily affected by the French generation and supply business as it had an 11.2 percent contraction and represents 37.5 percent of the group's earnings. The division suffered from lower nuclear generation, market share losses, and the negative effects on market purchases: the company had to

buy electricity at higher prices in the fourth quarter of 2016 to cover its electricity needs as production did not cover retail demand. The U.K. division showed a 23.6 percent contraction in earnings, despite the 7.4 percent increase in nuclear production, mainly driven by lower wholesale and retail prices, added to the erosion in market share and negative foreign exchange effects. The best-performing division was trading, with a 56.8 percent increase in profit, mainly due to the high volatility in power and gas markets. The renewable energy business had a positive year due to commissioned capacity and a strong Development and Sale of Structured Assets (DSSA), which generated a combined earnings growth of 6.1 percent. However, the renewables and trading performances achieved in 2016 are not expected to be replicated in 2017.

EDF decided in 2016 to apply an extension of the accounting depreciation of its 900 MW nuclear fleet from 40 to 50 years reducing the depreciation charges of the company by €1bn (US$1.08bn) or 11.6 percent, generating a positive effect on net income of €700m (US$754m). This has also created a €2bn (US$2.2bn) decrease in nuclear provisions and a €1.7bn (US$1.83bn) contraction in the scope of dedicated assets, used to cover the expected costs for nuclear decommissioning. This decision has been taken just before the ramp-up of its life-extension programme (Grand Carénage) with an investment envelope of €50bn+. Nonetheless, the life extension of nuclear assets in France has to be validated by the nuclear regulator, with no decision expected before 2018.

The group's operating income shrank by 3.4 percent, driven by earnings contraction plus higher provisions on the nuclear side, offsetting the positive effect from an increase in the accounting depreciation. Reported net debt remained stable at €37.4bn (US$40.3bn), which is a positive, although operating cash flows decreased by 12.6 percent year-on-year. Free cash flow continues to be on the negative side, but has eased with the help of the share dividend payment. The company expects to be cash-flow positive by 2018.

Looking forward, 2017 will be a decisive year for the company with the purchase of AREVA NP, expected results from the regulator on the Flamanville-3 EPR reactor vessel, added to multiple asset disposals and the end of the capital measures to ramp-up its balance sheet. The capital increase should allow the company to finance partially its multiple investment projects; but in a low-price environment and earnings-contracting trend, EDF still has a bumpy road ahead. The high reliance on nuclear does not support earnings in the short term. Asset disposals and scrip dividends are needed to cover cash flow deficits and high investment requirements. If everything happens according to the company's expectations, 2017 may be the bottom on the earnings side; however, there are too many unknowns to see a clear path.[9]

ENGIE

The restart of the Belgium nuclear assets at the end of 2015, following the approval of the life extension and tax agreements, helped the group's 2016 results by making a full-year earnings contribution. Nonetheless, their exposure to market prices across Oil & Gas, Liquefied Natural Gas (LNG), and power prices negatively impacted earnings, despite the fact that now close to 75 percent of the group's profits come from regulated or semi-regulated assets.

For 2016, ENGIE presented financial results with revenues falling 4.6 percent, earnings down 5.2 percent, and adjusted net income down 4.3 percent. On a reported basis, the group finished once again in negative territory with reported net income at –€0.4bn (–US$0.43bn) driven by €3.8bn (US$4.1bn) of impairments in power plants, nuclear assets and merchant activities.

The infrastructure segment continues to be the main profit driver as it reached a 2.3 percent increase and represents 32.4 percent of the overall profits. Latin America had an 8.5 percent increase in earnings, with a similar increase in Europe (+9.5 percent). Belgium's profits rose sharply (+69.5 percent) mainly due to the restart of three nuclear reactors in the country. In France, the group benefited from the positive weather effects on gas and electricity volumes to reach a 3.2 percent increase in profits, offsetting lower prices to both consumers and its power generation assets.

On the other hand, the LNG business has been harmed by the reduction in supply conditions, and lower geographical spreads on LNG prices, pushing profits down by 98.3 percent. Following this, the E&P business showed a 20.9 percent earnings decrease due to lower prices in both oil and gas and a 4.7 percent decrease in production.

Share prices hit the bottom in February 2017 at just over €11 per share, 75 percent down from its historic peak in June 2008, but has been slowly recovering since.

It seems that a better horizon is in sight, as the continued efforts of the company in its cost-cutting programme and a lower exposure to commodity prices should start to pay off. A more dynamic profile seems to be gaining momentum, as it should show organic growth across all business segments except North America (due to disposals). Thus, 2016 may be seen as the bottom in terms of earnings as the company expects 2017 growth despite the drag of asset disposals. The recovery is a positive and one year earlier than expected. It seems that the strategy to go towards a more network-oriented model would start to bear fruit.

In line with this, on 4 April 2017, ENGIE decided to step away from the NuGen nuclear project in the U.K. by transferring its 40-percent stake to Toshiba for ¥15.3bn (US$138.5m). The company decided to exercise its contractual rights on the project, which plans to build three Westinghouse AP1000 reactors. ENGIE estimates that NuGen has significant challenges, whereby the filing of Chapter 11 bankruptcy protection by Westinghouse was an event of default and allows the company the option to sell its stake to Toshiba, making Toshiba the sole stake owner of the uncertain project.[9]

ENEL

At the end of 2015, ENEL agreed with EPH ("Energeticky a Prumyslovy Holding", a privately-held Czech-Slovak holding company) to sell its 66 percent stake in its Slovakian assets for €750m (US$799m). The sale will be executed through the creation and transfer of ENEL's stake in Slovenské Elektrarne to a newly established company ("HoldCo"), with the later transfer of the HoldCo to EPH. The disposal agreement would be divided into two stages: 1) A €375m with the transfer of half of the HoldCo's share capital (50 percent) at signing, and 2) the transfer of the remaining shares of the holding company and the remaining €375m (US$399.5m) payment subject to the completion and operation of two nuclear reactors under construction at Mochovce in Slovakia since 1985 (now expected to be completed in late 2018 and 2019, respectively).

The adjustment mechanism would be calculated at the time of the reactors' completion and would include the net financial position, developments in energy prices in the Slovak market, operating efficiency levels, and the enterprise value of the company with the completion of the two reactors. In addition to this, ENEL has signed a Memorandum of Understanding with the Slovak Ministry of Economy validating the agreement. This has allowed the company to deconsolidate the assets from its accounts in 2016, reducing their nuclear capacity and the provisions for those.

On the financial side, the Italian group has presented its 2016 results with revenues decreasing 6.7 percent, EBITDA in line with last year's level, but net income increasing 17 percent driven by lower income taxes and minority interests, offsetting the 13 percent increase in interest expenses. On recurrent earnings adjusted for one-offs, EBITDA increased by 1 percent and net income by 12.3 percent. A dividend of €0.18/share will be paid. The strong results at the net income level has allowed the company to strengthen its balance sheet further as it has increased by 7.5 percent its equity levels. The relatively flat net debt has been mainly due to the 21.7 percent decrease in the cash reserve, as the company has obtained a 3 percent decrease in gross debt. Hence, the financial structure has strengthened as the company has reduced its gearing (net debt/equity).

The company expects for 2017 a further growth in profits with EBITDA reaching +2 percent, net income +10 percent, and a minimum dividend payment of €0.21/share representing a 16 percent increase with a 65 percent payout ratio (US$0.22/share). The group proposed the buy-back of 500 million shares, or a total of €2bn (US$2.12bn) in addition to a similar amount for a minority buy-out. ENEL's objectives for 2017 onwards are reassuring with higher profits both at the top and bottom line levels, added to a greater return expected for shareholders. The group has a well-diversified generation portfolio, a strong presence in developing economies with demand growth, and a resilient positioning within the network business. Investment towards growth has been revised upwards, towards projects with a low-risk profile with a commissioning expected in less than three years.[9]

TEPCO

The Japanese Ministry of Economy, Trade, and Industry (METI) raised the expected budget for the decommissioning and decontamination of Fukushima based on the updated estimates provided on 9 December 2016. This will now cost twice as much as originally expected. The total costs are expected now at ¥22 trillion (US$220bn). According to the ministry, the cost of decommissioning the damaged reactors will increase to ¥8 trillion (US$72bn), while the compensation will rise to ¥8 trillion (US$72bn), which makes TEPCO responsible for ¥16 trillion (US$144bn) for the clean-up process. The company's shares fell close to 3 percent after the new estimates were provided. TEPCO's share value had been wiped out after the 3/11 events. While much of the decline from the February 2007 peak value had already happened prior to 3/11, in early July 2017, barely more than one tenth of that share price was left.

Moreover, in March 2017 the district court in Maebashi (North of Tokyo), ruled in favour of evacuees from the Fukushima Daiichi plant seeking damages for being removed from their homes due to radiation dangers. It is the first time a court has recognised that the Japanese government has liability over the accident, stating that both

TEPCO and the government are liable for negligence, making it necessary to award compensation damages to the victims.
For the company to be able to cover the increased costs, the Japanese government increased the credit line from ¥9 to ¥13.5 trillion (from US$82 to US$123bn). Driven by higher expected costs and compensation damages, the company, which was once Asia's largest utility and was essentially nationalised after the 3/11 accidents, has decided to tap debt markets for the first time since then, as the company mandated six investment banks to sell bonds worth ¥100bn (US$890m). The objective is to re-enter the bond market in 2017 and restart regular bond issuance in order to help to pay the compensation costs in addition to the credit line provided by the government.
On its financial results in 2016 (third quarter), TEPCO had a 13.8 percent contraction in operating revenues to ¥3.88 trillion (US$35.3bn), decreasing for a second consecutive year due to a decrease in the price of electricity from fuel cost adjustments. Despite this, cost decreases from lower fuel expenses and cost optimisation measures have allowed the company to post profits in the positive side for a second year with net income reaching ¥306bn (US$2.8bn), but representing a 29.8 percent decrease from a year earlier. Up to date, the cumulative financial impact of the 3/11 disaster for the company has been revised upwards from ¥6.35 to 6.66 trillion (from US$57.9bn to 60.7bn).[9]

TOSHIBA

Toshiba had major hiccups with its subsidiary Westinghouse after the group took over CB&I Stone and Webster in 2015 to resolve disputes related to cost increases from changes in NRC's regulation. Following this, the company became fully liable for any delays and cost overruns on two different nuclear projects under construction in the U.S., making the group to book close to US$6.8bn of impairments in the first half of 2016.
On 29 March 2017, the company decided that Westinghouse would file for bankruptcy protection in the U.S. This allows Toshiba to deconsolidate Westinghouse from its accounts, but would force the company to book losses close to US$9bn. After the decision and the multiple scandals concerning the company's management policies, shareholders have openly declared that they have doubts over any revival plan after the Westinghouse bankruptcy filing.
On 11 April 2017, the company decided to publish its 9-month results without the signature of the auditors, as the auditors (PricewaterhouseCooper) have concerns that the previous accounting figures provided by Westinghouse are not proper. Toshiba published without a signature after two previous postponements to avoid a further delay. With the publication, Toshiba raised a flag over its ability to continue as a going concern, driven by their increasing losses and negative equity levels. Revenues decreased 4 percent to ¥3,847bn (US$33.2bn) and operating loss by 149 percent to ¥576.3bn (US$5bn), while net loss widened to ¥532.5bn (US$4.6bn).
Following Westinghouse-bankruptcy news, SCANA, which is developing two AP1000 reactors in South Carolina, decided to continue with the project through a transition and validation period. In March 2017, SCANA announced it would evaluate all options before giving a response to the regulator on the "most prudent path to follow". On 31 July 2017, SCANA Corporation571 and Santee Cooper (formally, the South Carolina Public Service Authority) announced that they were halting construction. Southern Co. is facing a similar decision on two AP1000 reactors under construction at the Vogtle plant in Georgia. In order to cover some of the expected losses from the nuclear side, the Japanese group is divesting part or all the shares of its most profitable business: the memory chip unit. Moreover, in a meeting with its creditors over a third extension waiver for breach of covenants on syndicated loans, the group has proposed some shares of its chip business as collateral to secure debt refinancing (rights to the assets to secure borrower's loan).[9]

EXELON

In 2016, Exelon reported revenues increasing by 6.5 percent. However, lower margins, higher depreciation charges, and an increase in operating expenses shrank the group's earnings by 29.4 percent. In addition, higher interest expenses (+50.7 percent) reduced the group's reported net income by 50 percent. On an adjusted basis, EPS reached US$2.68bn, a 7.6 percent increase.
On the nuclear side, in 2016 the company achieved a nuclear capacity factor of 94.6 percent – the best in the company's history. Nonetheless, nuclear investment has been substantially revised downwards (–29.7 percent), as almost all the envelope would be for maintenance (84.6 percent).
Exelon expects a flat performance for 2017 as it targets adjusted net income to fluctuate between –6.7 percent and +4.5 percent. The group expects to decrease its investment in the coming years, while simultaneously targeting an increase on its regulated asset base (RAB) of 6.5 percent. The nuclear business is expected to be affected by lower energy prices, which would hit margins and drop profits by –17.3 to –9.5 percent. It is clear that the company cur-

rently follows the sectoral trend of lower reliance of nuclear earnings and higher exposure to networks and regulated assets to support profits and growth.
Driven by the low power price environment, Exelon and other nuclear operators in the U.S. are demanding new nuclear subsidies to continue operations as profitability erodes. In August 2016, the New York regulator approved a $500m/year subsidy for the company to avert imminent closures of its Ginna and Nine Mile Point reactors. Moreover, Illinois approved the payment of $235m/year for 10 years to keep the Quad Cities and Clinton reactors open. Nuclear operators are seeking direct subsidies in Ohio, Connecticut, Pennsylvania and New Jersey. In many states, operators have stated that if no subsidies were given, they would be forced to close operations as profitability is rapidly decreasing. The subsidies, if approved, would be financed through higher tariffs charged to end-consumers. Those already awarded are being challenged in court, and those proposed are reportedly meeting with less enthusiasm.[9]

New reactor development

Most of the anticipated growth in nuclear capacity in the coming decades will come with the deployment of "large" Gen III reactors (in the range 1000-1700 MW unit size, see Table 2), either PWRs or BWRs, though some deployment of SMRs, PHWRs or Gen IV reactors. Gen III reactors have enhanced safety features and higher efficiency, as well as improved fuel economy compared with Gen II reactors.
Only evolutionary changes and innovations in Gen III technology are foreseen up to 2050, with efforts to simplify and standardise the designs. This will help to improve their constructability and modularity, which should reduce costs and shorten construction spans.

Vendor	Country	Design	Type	Net capacity (MW)	In operation*	Under construction*
AREVA	France	EPR	PWR	1 600	0	4 (Finland, France, China)
AREVA/MHI	France/ Japan	ATMEA	PWR	1 100	0	0
CANDU Energy	Canada	EC6	PHWR	700	0	0
CNNC-CGN	China	Hualong-1	PWR	1 100	0	0
GE Hitachi – Toshiba	United States/ Japan	ABWR	BWR	1 400-1 700	4 (Japan)	4 (Japan, Chinese Taipei)
GE Hitachi		ESBWR	BWR	1 600	0	0
KEPCO/KHNP	Korea	APR1400	PWR	1 400	0	7 (Republic of Korea, United Arab Emirates)
Mitsubishi	Japan	APWR	PWR	1 700	0	0
ROSATOM	Russia	AES-92, AES-2006	PWR	1 000-1 200	1	10 (Russia, Belarus, China, India)
SNPTC	China	CAP1000, CAP1400	PWR	1 200-1 400	0	0
Westinghouse/ Toshiba	United States/ Japan	AP1000	PWR	1 200	0	8 (China, United States)

Table 2. Examples of Gen 3 reactors.
Source: OECD/IEA and OECD/NEA. Technology roadmap. Nuclear energy. Paris. 2015 [8]

In terms of operation, base-load power production is the most cost efficient way to operate an NPP. Having large shares of variable renewable electricity production will require more thermal plants to deal with backup and provide flexibility. Thus, there needs to be a better integration of nuclear, thermal and renewables from an electricity system and market perspective, to avoid loss of production and improve cost efficiency, taking into account the peculiarities of each technology. Operators supply electricity to customers in a competitive marketplace, where overall cost is an important parameter.[8]
In the long term, there is also a need to take into account possible changes in the climate to ensure that NPPs are resilient both in the face of extreme weather events as well as under higher ambient air and cooling water conditions. Issues such as increased risk of flooding through intense precipitations, storms or sea level rise need to be addressed, by designing appropriate barriers and selecting less exposed sites. The availability and quality of water for cooling of NPPs will also be a matter for concern, especially for inland plants located on rivers that use once-through cooling. High cooling water temperatures reduce the thermal efficiency and electrical output of NPPs, and this can be compensated by more efficient heat exchangers. Closed cycle cooling or advanced cooling technologies that reduce the consumption of water, as well as the use of non-traditional sources of water (treated waste water, for instance), will need to be developed.[8]
The start of the deployment of Gen IV reactors is not foreseen before 2030. For many decades after that, Gen IV reactors will likely be deployed alongside advanced Gen III reactors, but in far smaller numbers. Yet, because of the potential benefits that these reactors can bring, R&D and demonstration projects, especially in the area of fuels

and materials that can withstand higher temperatures, higher neutron fluxes or more corrosive environments, are needed to bring concepts towards commercialisation. Prototype development and testing (see Table 3) is seen as particularly important. Construction and operation of Gen IV prototypes in the period 2020-30 are necessary if Gen IV technology is to be deployed commercially from 2030 onwards; see Figure 1.[8]

Tools of nuclear science

Presently, the most commonly used tools of nuclear science are accelerators, reactors, detectors, and computers. The technological development of these devices has gone hand in hand with advances in nuclear science, sometimes leading and sometimes following closely behind. We believe scientific laboratories can find industry partners for joint research and development projects in this area. Selected tools for nuclear power are indicated below.

Vendor	*Country*	*Design*	*Type*	*Net capacity (MW)*	*In operation**	*Under construction**
Babcock & Wilcox	United States	mPower	PWR	180	0	0
CNEA	Argentina	CAREM-25	PWR	25	0	1
CNEC	China	HTR-PM	HTR	210	0	Twin units
CNNC	China	ACP-100	PWR	100	0	0
KAERI	Korea	SMART	PWR	110	0	0
NuScale	United States	NuScale SMR	PWR	45	0	0
OKBM	Russia	KLT-40S	Floating PWR	2x35	0	Twin units (one barge)

Table 3. Examples of small modular reactor designs.
Source: OECD/IEA and OECD/NEA. Technology roadmap. Nuclear energy. Paris. 2015 [8]

Figure 1. Evolution of fission reactor technology.
Source: OECD/IEA and OECD/NEA. Technology roadmap. Nuclear energy. Paris. 2015.[8]

Nuclear reactors created not only large amounts of plutonium needed for the weapons programmes, but a variety of other interesting and useful radioisotopes. They produced 60Co, in which the non-conservation of parity was first discovered, and a number of transuranic isotopes that are used to study the limits of the periodic table. Reactors also produce isotopes for commercial and medical purposes:

1. 241Am—used in smoke detectors,
2. 60Co—used in industry to inspect weld quality, also used in cancer therapy,
3. 99mTc—used for medical diagnosis, and

4. 137Cs—also used for medical therapy.
Reactor neutrons have been used for material studies that involve their scattering from the crystal planes.[7]

Detectors: The interactions of alpha, beta, and gamma radiations with matter produce positively charged ions and electrons. Radiation detectors are devices that measure this ionisation and produce an observable output. Early detectors used photographic plates to detect "tracks" left by nuclear interactions. The cloud chambers, used to discover sub-nuclear particles, needed photographic recording and a tedious measurement of tracks from the photographs. Advances in electronics, particularly the invention of the transistor, allowed the development of electronic detectors. Scintillator-type detectors use vacuum tubes to perform the initial conversion of light to electrical pulses. The amplification and storing of these data follow the advances in transistor electronics. Miniaturisation in electronics has revitalised types of gas-filled detectors. These detectors were developed as "single element" detectors and now have been revived into "multiple element" detectors with more than one thousand elements. Advances in materials, particularly ultra-pure materials, and methods of fabrication have been critical to the creation of new and better detectors.[7]

As the requirements for greater accuracy, efficiency, or sensitivity increases, so does the complexity of the detector and its operation. The following list presents some types of commonly used detectors and includes comments on each of them.

Geiger counter: The detector most known to the public is the Geiger-Mueller counter, commonly called the Geiger counter. It uses a gas-filled tube with a central wire at high voltage to collect the ionisation produced by incident radiation. It can detect alpha, beta, and gamma radiation although it cannot distinguish between them. Because of this and other limitations, it is best used for demonstrations or for radiation environments where only a rough estimate of the amount of radioactivity is needed.

***Scintillation detectors*:** Scintillators are usually solids (although liquids or gases can be used) that give off light when radiation interacts with them. The light is converted to electrical pulses that are processed by electronics and computers. Examples are sodium iodide (NaI) and bismuth germanate (BGO). These materials are used for radiation monitoring, in research, and in medical imaging equipment.[7]

Solid-state x-ray and gamma-ray detectors: Silicon and germanium detectors, cooled to temperatures slightly above that of liquid nitrogen (77 K), are used for precise measurements of x-ray and gamma-ray energies and intensities. Silicon detectors are good for x-rays up to about 20 keV in energy. Germanium detectors can be used to measure energy over the range of >10 keV to a few MeV. Such detectors have applications in environmental radiation and trace element measurements. Germanium gamma-ray detectors play the central role in nuclear high-spin physics, where gamma rays are used to measure the rotation of nuclei. Large gamma-ray detection systems, such as AGATA, Gammasphere and Eurogam, are made of these detectors.[7]

Low-energy charged-particle detectors: Silicon detectors, normally operated at room temperature, play a major role in the detection of low-energy charged particles. Singly, they can determine the energy of incident particles. Telescopes (combinations of two or more Si detectors) can be used to determine the charge (Z) and mass (A) of the particle. This type of detector is used in environmental applications to look for alpha-particle emitters (such as radium) in the environment.

Neutron detectors: Neutrons are much harder to detect because they are not charged. They are detected by nuclear interactions that produce secondary charged particles. For example, boron trifluoride (BF3) counters make use of the $^{10}B(n,\alpha)^{7}Li$ reaction to detect neutrons. Often one uses a moderator, such as paraffin, to slow the neutrons and thus increase the detection efficiency. These detectors are used to monitor the neutron fluxes in the vicinity of a reactor or accelerator. Liquid scintillators can measure both neutrons and gamma rays. By carefully measuring the shape of the electronic signal, scientists can distinguish between these two types of particles.[7]

Neutrino Detectors: Neutrinos interact very weakly with matter and are therefore very hard to detect. Thus, neutrino detectors must be very large. The Sudbury Neutrino Observatory in Canada was developed to understand the solar neutrino problem (too few neutrinos come out of the Sun than expected) and contains an active volume of 1000 tonnes (metric tons) of deuterium oxide (heavy water). This is a Cherenkov counter, in which the interaction of the neutrino with the heavy water produces an electron moving faster than the speed of light in water. The moving electron generates a cone of light that can be observed with photomultiplier tubes. Information from these tubes provide the information to determine the energy and direction of the incident neutrino.[7]

High-energy charged-particle detectors: As the energy increases, large and even more complex detection systems are needed, some involving thousands of individual detectors. These detectors typically involve the "tracking" of large numbers of particles as they pass through the detector. Large magnets are required to bend the paths of the charged particles. Multi-wire detection systems with nearly a quarter of a million channels of electronics provide information on these tracks. High-speed computer systems process and store the data from these detectors. Similarly, powerful computer systems are needed to analyse these data so that a scientific discovery can be made.

Computers: Beginning in the 1970s, computers played a role in nuclear science that developed from relatively minor to significant. Before this time, computers were used for calculations to develop and refine theories in nuclear science. As computers moved to being interfaced with detectors and accelerators, they became inseparable from the experiment. Indeed, the design of detectors for large experiments includes the integration of computer systems into each detector element. Computers are still used to make predictions of experiments based on various theories. Only the most powerful computer systems can generate simulations of the expected data from today's giant experiments. Similarly, only the most powerful computers can process the data that come from these experiments.

Other Sciences and Technologies

While technology has been a driving force for nuclear science research, this field has similarly pushed the limits of technology. Likewise, advances in other scientific disciplines have been important to the progress in nuclear science. Development and advances in chemistry were essential to the discovery of most of the transuranic elements. This technology is still used to separate chemical species and allows studies of nuclei produced in accelerator or reactor experiments. Advances in solid-state physics have produced larger and better silicon and germanium detectors for use in x-ray, gamma ray, and particle spectroscopy.[7]

Medical technology

Medical technology is any technology used to save lives of individuals suffering from a wide range of conditions. In its many forms, medical technology is already diagnosing, monitoring and treating virtually every disease or condition that affects us.

The common thread through all applications of medical technology is the beneficial impact on health, quality of life and society as a whole. Medical technologies all contribute to living longer and better, and empower citizens to contribute to society for longer. In so doing, they improve the quality of care and the efficacy, efficiency and sustainability of healthcare systems.

Innovations in medical sector

Medical technology is characterised by a constant flow of innovations, which are the results of a high level of research and development within the industry, and of close co-operation with the users. Products typically have a lifecycle of only 18-24 months before an improved product becomes available.

In 2016, more than 12,200 patent applications were filed with the European Patent Office (EPO) in the field of medical technology, i.e. 7.7% of the total number of applications but still more than any other sector in Europe. Of these patent applications, 41% were filed from European countries (EU28, Norway and Switzerland) and 59% from other countries, the majority of which filed from the US (38%).

In comparison, around 5,700 applications were filed in the pharmaceutical field and around 5,700 also in the field of biotechnology. While the number of EPO filings in the field of medical technology has doubled over the last decade, pharma and biotech patent applications were relatively stagnant; see Figure 2.

What constitutes medical technology innovation continues to evolve. Technological advances in sensors, coupled with advances in artificial intelligence (AI), are broadening the definition of MedTech to include digital products and data-driven services. Given this continued march of technology, industry convergence will continue to accelerate, lowering barriers to entry for new entrants, especially those that specialise in software-based or other customer-focused services.

To thrive in this era of rapid and continual change, medical technology must build flexible business models that balance investments in internal R&D and external innovation.

In 2016–17, signs of the medical technology industry's growing interest in collaborations with tech and digital players continued despite little direct evidence that these alliances have generated additional medical technology revenue.

In the future, medical technology may look to create holistic care platforms that evolve from a disease- or technology-specific focus to managing complicated patients across the care continuum. Such platforms of care could assist providers and payers with one of their most pressing issues: the efficient delivery of high-quality, high-touch care across populations with multiple co-morbidities.

As populations around the globe age, the need for such consumer-focused platforms is only growing more acute. By 2050, the world's population over 65 is expected to triple.

If structured correctly, these emerging platforms will enhance the patient experience and create new revenue opportunities for medical technology. For instance, by linking big data capabilities with new knowledge from precision medicine, it will be possible to create precision health offerings that promote preventive interventions before symptoms of disease manifest. The goal is to use digital tools and smart devices to nudge individuals with the right piece of information, cue or intervention at the exact right moment in time to maintain health. Such responsive platforms will not only be valuable to individual patient consumers. They will also be valuable to providers and health systems that are reimbursed according to the value and quality of the care they deliver.
As medical technology continue to transform their business models to increase customer-centricity, the types of partners they need to engage will only expand.[4]

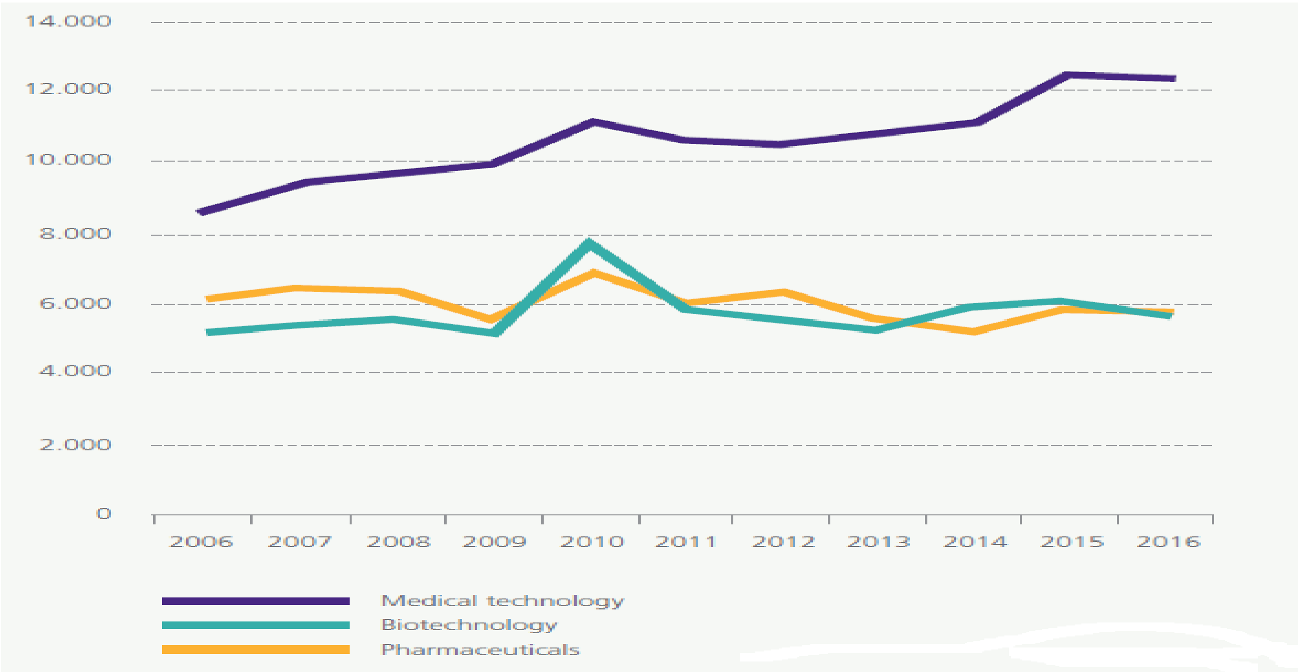

Figure 2. Evolution of European patent application by technical field.
Source: European Patent Office, MedTech Europe calculations. Medical technology as defined by World Intellectual Property Organisation (based on the WIPO IPC-Technology concordance as revised in August 2014). European countries refer to EU + Norway, Switzerland. Patents are attributed by the country of residence of the applicant. [4]

Radioisotopes

Radioisotopes are used in medicine for the diagnosis and treatment of various diseases, including some of the most important ones, like cancers, or cardiovascular and brain diseases. Over 10000 hospitals worldwide use radioisotopes for the in-vivo diagnosis or treatment of about 30 million patients every year, including 7 million in Europe. The majority of today's nuclear medicine procedures are for diagnosis, with about 100 different imaging procedures available. Imaging using radioisotopes is often indispensable, for instance due to its ability to identify various disease processes early, long before other diagnostic tests. Technetium-99 m (Tc-99 m) is the most widely used (diagnostic) radioisotope. The production of Tc-99 m is a complex process, which includes irradiation of uranium targets in nuclear research reactors to produce Molybdenum-99 (Mo-99), extraction of Mo-99 from targets in specialised processing facilities, production of Tc-99 m generators and shipment to hospitals. Due to their short decay times, Mo-99 and Tc-99 m cannot be stockpiled and must be produced continuously and delivered to hospitals weekly. Any supply disruption can have negative and sometimes life-threatening consequences for patients.[11]

The most important companies in the medical industry

MEDTRONIC

The leading medical device company in the world, Medtronic, enjoyed a staggering 42% growth in revenue compared with 2015 figures ($20.3 billion). The medical device giant operates in over 140 countries and employs more than 100,000 people that work across its principal units: cardiovascular, diabetes, spinal and biologics, neuromodulation, surgery and cardiac rhythm disease. Much of 2016 growth ($29bn) can be attributed to the completion of a very successful acquisition of MedTech company Covidien. Medtronic will integrate Crospon into its respiratory, gastrointestinal and informatics division. With Crospon's addition, Medtronic will have leading solutions from diagnosis to therapy for oesophageal diseases. Crospon is based in Galway, where many U.S. and European medical-device companies have facilities.

JOHNSON & JOHNSON

The second biggest medical device company is American biopharmaceutical, consumer goods and medical device giant Johnson & Johnson, which has been a well-known household name across the globe for several decades. Their high position on the market is based on the revenue from the company's medical device subsidiaries that include Ethicon, Acclarent and DePuy Synthes. The group develop and manufacture products in various therapy areas: orthopaedic, cardiovascular, diabetes, vision care and surgery. The company saw a 2.6% increase in revenue in 2016. Through greater innovation, portfolio management and by expanding into emerging markets the company generated $20.2 billion in revenue for 2017, an increase of 11.5 percent from the previous year. On an operational basis, J&J's revenue grew 9.4 percent. In summer 2017, J&J closed a $30 billion deal for Swiss biotech company Actelion.

GE HEALTHCARE

In the top three medical device companies in the world, General Electric is another multinational conglomerate that has a thriving healthcare segment, commonly known as GE Healthcare. The company produces medical devices like x-ray generators, ultrasound machines, incubators and CT image machines. It also develops devices that aid research and drug innovation and biopharmaceutical manufacturing. In 2016, the company experienced healthy 17.3% margin and in 2017, it aims to grow by expanding further into emerging markets and China. Recently, GE Healthcare has committed $300million under their initiative, Sustainable Healthcare Solutions, which aims to bring 'disruptive technologies' to the emerging markets where healthcare is less accessible.

FRESENIUS (MEDICAL CARE)

German medical devices company Fresenius Medical Care specialises predominately in developing medical supplies to treat patients with renal (kidney) diseases, particularly to aid dialysis. The company attributes strong growth ($18bn) of 7% in 2016 to an increase in sales of dialysers and machines as well as positive price and volume effects. It also grew its workforce from 104,033 in 2015 to 109,319 in 2016, a 5% increase. Fresenius Medical Care intends to boost annual revenues to $28 billion by 2020.

PHILIPS (HEALTHCARE)

Philips is a global conglomerate company that is the largest manufacturer of lighting in the world. Their healthcare segment is also hugely successful, developing medical devices in a number of therapy areas including anaesthesia, oncology and cardiology. The company experienced a 3% growth in sales in 2016 in part thanks to a series of successful growth initiatives, including the acquisition of PathXL in June 2016 and the integration of Volcano back in 2015. Philips continues to progress with its EUR 1.5 billion-share buyback programme, which was initiated in the third quarter of 2017 for capital reduction purposes. Comparable order intake increased 6% compared to 2016. Net income from continuing operations, which included a one-time non-cash tax charge of EUR 72 million, increased to EUR 1,028 million, compared to EUR 831 million in 2016. Adjusted EBITA margin improved by 110 basis points to 12.1% of sales, compared to 11.0% of sales in 2016. Income from operations (EBIT) amounted to EUR 1,517million, compared to EUR 1,464 million in 2016.

SIEMENS (HEALTHINEERS)

This multinational conglomerate company renamed its healthcare segment from Siemens Healthcare to Siemens Healthineers in 2016. The innovative healthcare provider boasts an impressive portfolio of medical imaging and laboratory diagnostics, and is currently working to use its scientific and engineering expertise to expand into digital services and therapeutic and molecular diagnostics. Following Siemens' 2020 Vision restructuring, Healthineers has enjoyed steady growth in 2015 and 2017 and the company expects to continue this into 2017, especially in markets such as the USA and China.

Models cooperation in network between scientific centres and industry

In reference to those indicated industry we propose models of cooperation between scientific centres and business partners. The success of partnership between scientific organisations and industry depend on the degree of openness to cooperation based on the transfer of knowledge and technology. The first proposed model of cooperation is based on the concept of an open innovation model.

Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology. However, many enterprises and research centres are still working according to the closed innovation model. The logic behind is that informed closed innovation thinking was an internally focused logic. This logic was not necessarily written down in any single place, but it was tacitly held to be self-evident as the “right way” to innovate. Here are some of the implicit rules of closed innovation:

- We should hire the best and the brightest people, so that the smartest people in our organisation work for us.
- In order to bring new solutions and technologies to the market, we must discover and develop these ourselves.
- If we discover it ourselves, we will get it to market first.
- The organisation that gets an innovation to the market first will usually win.
- If we lead the industry in making investment in research and development (R&D), we will discover the best and the most ideas and will come to lead the market as well.
- We should control our intellectual property, so that our competitors do not profit from our ideas.

The logic of closed innovation created a virtuous circle; see Figure 3. Organisation invested in internal R&D, which led to many breakthrough discoveries. These discoveries enabled the organisation to bring new products, solutions, services to the market, to realise more sales and higher margins because of these products, and then to reinvest in more internal R&D, which led to further breakthroughs. Furthermore, because the intellectual property (IP) that arises from this internal R&D is closely guarded, others could not exploit these ideas for their own profit. For most of the twentieth century, this paradigm worked, and worked well. Moreover, many government institutions created *ad hoc* central research laboratories to make projects based on this paradigm.[2]

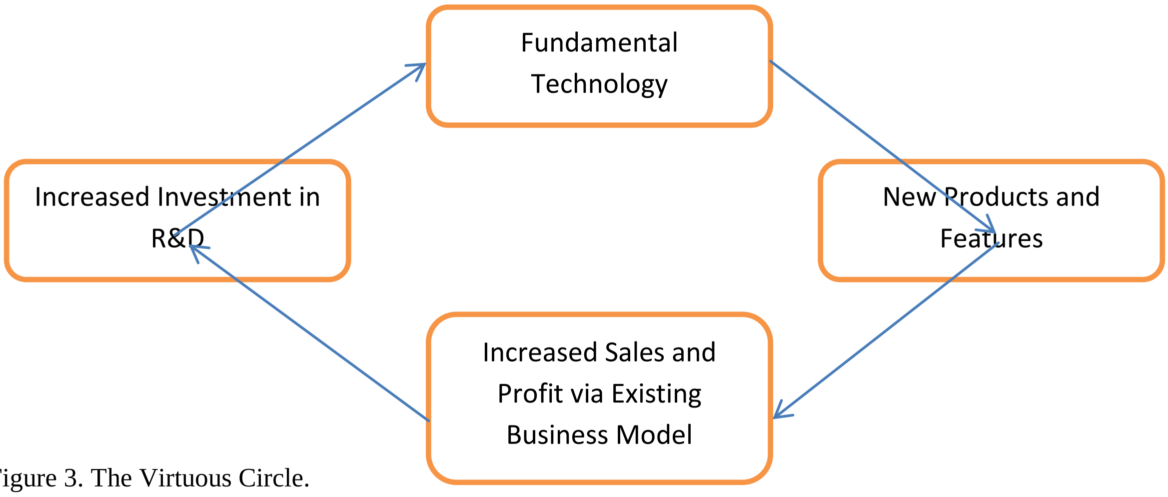

Figure 3. The Virtuous Circle.
Source: Chesbrough H.: Open Innovation. The new imperative for creating and profiting from technology. Harvard Business School Press. Boston. 2003[2]

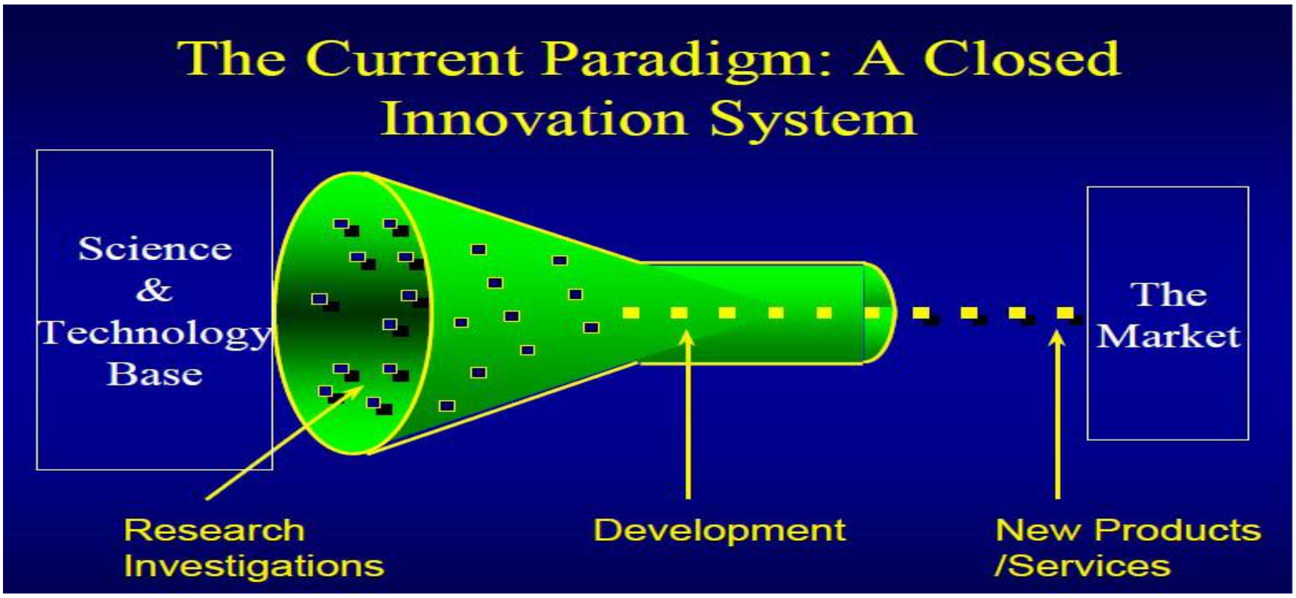

Figure 4. The closed paradigm for managing industrial R&D.
Source: Chesbrough H.: Open Innovation and Open Business Models: A new approach to industrial innovation. Presentation to Joint OECD/Dutch Ministry of Economic Affairs. Conference on “Globalisation and open innovation” December 2006[1]

Figure 4 depicts this Closed Innovation paradigm for managing R&D. The yellow solid lines show the boundary of the organisation. Ideas flow into the organisation on the left and flow out to the market on the right. They are screened and filtered during the research process, and the surviving ideas are transferred into development and then to market.

The linkage between research and development is tightly coupled and internally focused. Our extant theories of managing R&D are built on this conception. Examples of this thinking are the stage gate process, the chain link model, and the product development funnel or pipeline found in many cases on managing R&D. Projects enter on the left at the beginning, and proceed within the organisation until they are shipped to customers on the right of the figure. The process is designed to weed out false positives, i.e. projects that look initially appealing, but later turn out to be disappointing. The surviving projects, having survived a series of internal screens, hopefully have a greater chance of success in the market.[2]

The factors, like the growing mobility of highly experienced and skilled people, growing new firms that commercialised external research, products life cycle, adoption of innovation, new standards in managing of innovation projects, managing of risk investment of innovation projects and managing of IP, have influence for erosion of closed innovation. When fundamental technology breakthroughs occurred, the scientists and engineers who made these breakthroughs were aware of an outside option that they formerly lacked.

In situations, in which these erosion factors have taken root, closed innovation is no longer sustainable. For these new situations, a new approach, open innovation, is emerging in place of closed innovation. Open innovation is the paradigm that assumes that organisations can and should use external ideas as well as internal ideas, and internal and external paths to market, as the organisations look to advance their technology. Open innovation combines internal and external ideas into architectures and systems whose requirements are defined by a business model. This model utilises both external and internal ideas to create value, while defining internal mechanisms to claim some portion of that value. Open innovation assumes that internal ideas can also be taken to market through external channels, outside the current businesses of the organisation, to generate additional value.[2]

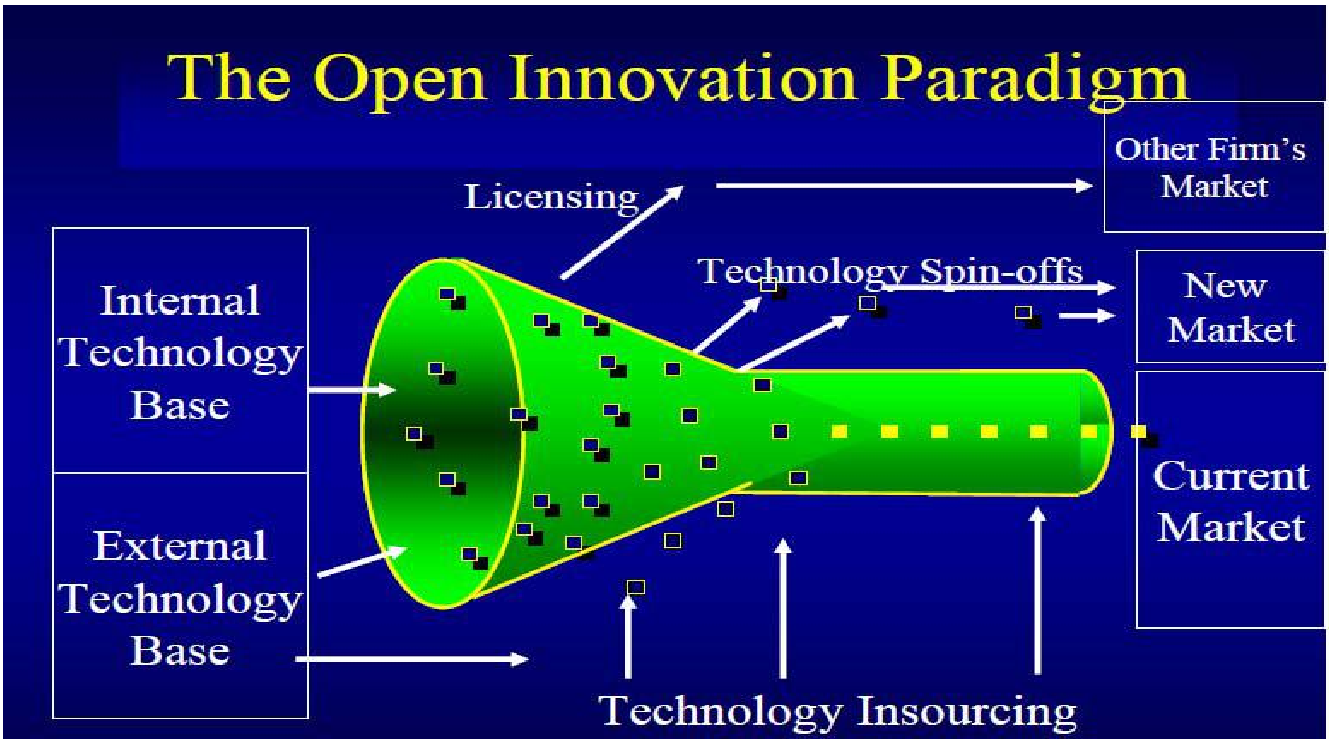

Figure 5. The open innovation paradigm for managing industrial R&D.
Source: Chesbrough H.: Open Innovation and Open Business Models: A new approach to industrial innovation. Presentation to Joint OECD/Dutch Ministry of Economic Affairs. Conference on "Globalisation and open innovation" December 2006[1]

In Figure 5, ideas can still originate from inside the organisation's research process, but some of those ideas may seep out of the firm, either in the research stage or later in the development stage. A leading vehicle for this leakage is a start-up company, often staffed with some of the organisation's own personnel. Other leakage mechanisms include external licensing and departing employees. Ideas can also start outside the organisation's own labs and can move inside. As Figure 5 shows, there are a great many potential ideas outside the organisation. In the figure of the closed model, the solid lines of the funnel represented the boundary of the organisation. In the figure of the open model, the same lines reflect the more porous boundary of the organisation, the interface between what is done inside the organisation and what is accessed from outside the organisation.
Although the open innovation process still weeds out false positives (now from external as well as internal sources), it also enables the recovery of false negatives, that is, projects that initially seem almost worthless, but turn out to be surprisingly valuable. Often these projects find value in new markets, rather than in the current markets, or they may be worthwhile if they can be combined with other projects. These opportunities were frequently overlooked by the earlier closed innovation process.
At root, the logic of open innovation is based on a landscape of abundant knowledge, which must be used readily if it is to provide value to the organisation that created it. The knowledge that a company uncovers in its research cannot be restricted to its internal pathways to market. Similarly, its internal pathways to market cannot necessarily be restricted to using the company's internal knowledge. This perspective suggests some very different organising principles for research and for innovation.
In contrast to closed innovation, the open innovation shows new paradigm and logic (see also Table 4):

- Not all the smart people work for us. We need to work with smart people inside and outside our organisation.
- External R&D can create significant value; internal R&D is needed to claim some portion of that value.
- We do not have to originate the research to profit from it.
- Building a better organisation model is better than getting to market first.
- If we make the best use of internal and external ideas, we will win.
- Good ideas are widely distributed today. No one has a monopoly on useful knowledge anymore.
- Innovation is now done within networks of firms, rather than within a single firm.

- We should profit from other's use of our IP, and we should buy others' IP when-ever it advances our own organisation model.[2]

Closed innovation	Open innovation
- Exclusive use of internal R&D - Technology invented, protected, developed, brought to the market and distributed by the same company - Full internal control of the innovation – from R to D to C - Technology exploited only through internal business model - IP generators of new technologies – mainly Companies - Companies usually selling but not buying IPRs (advantage – no confusion about IP ownership) - IP valuation method – Discounted Cash Flow – "Net Present Value" of the technology - Lack of IP market	- Use of internal and external R&D and inventions – corresponding to the particular business models - Openness to external business models - Variety of IP generators and collaborators – other companies, public universities and R&D institutions, users, customers, suppliers… - Active IP asset management of the companies' IP portfolio – matching technologies with innovative (inside or external) business models to add value to IP - More proactive assertion of IP policy - Development of Intermediate IP Markets –semiconductors, biotechnology, chemicals and other - Use of more complex IP valuation methods – such as "Real Option" – imposed by very intensive and diversified IP commercialisation models – reassignment of the IP to different partners during its legal life, selling/buying, licensing (to companies or start-ups) - IP an asset which can (and should) be managed through an adequate business model in order to increase value and become a reliable source of revenue.

Table 4. The comparison of close and open innovation model on the IP level.
Source: Spasic O.: Business Model of Innovation – "Closed Innovation" and "Open Innovation". National workshop on innovation promotion and technology transfer". Belgrade. June 2011. [10]

CERN and leading ICT companies - case study

The CERN Open Lab is a microcosm of CERN and is example of OI2 in action focused on shared purpose. The CERN Open Lab is a unique public-private partnership that accelerates the development of cutting-edge solutions for the worldwide LHC community and wider scientific research. The unofficial mantra of the CERN Open Lab is 'you make it, we break it' meaning the Open Lab community pushes new emerging technologies to the extremes, for the extreme operating demands of the CERN Large Hadron Collider and in doing so also discovers the operating boundaries of new high-tech products and services from ICT industry.

In the CERN Open Lab, CERN collaborates with leading ICT companies and research institute, provides access to its complex IT infrastructure and its engineering experience, and occasionally extends this access to collaborating institutes worldwide. Testing in CERN's demanding environment allows CERN to assess the merits of new technologies in their early stages of development for possible future use, provides the ICT industry partners with valuable feedback on their products while providing academic research institutes unparalleled access to domain and industry expertise and products. This ecosystem provides a neutral ground and platform for carrying out advanced collaborative.

The longevity and growth of the CERN Open Lab, now over 15 years in existence, demonstrates the shared value created by participating collaborators. Open Lab delivered a long list of technical achievements, which played a vital role in the discovery of the Higgs Boson particle. As part of shared purpose, the CERN Open Lab also demonstrates a significant commitment to education, with funding provided for young researchers to build the pipeline for the next generation of talent. Work of the Open Lab demonstrated the virtuous circle between basic and applied research at work.

The CERN Open Lab practices at the frontier of digital innovation and currently focuses research on topics such as data acquisition, computing platforms, data-storage architectures, computing provisioning management, network and communication, and data analytics.[3]

The second model of cooperation in network between scientific units and industry is model of technological innovation. The model shows the process of transformation of information among four industrial institutions: Production, Design and Development (D&D), Industrial Research and Development (R&D) and Basic Research; see Figure 6.

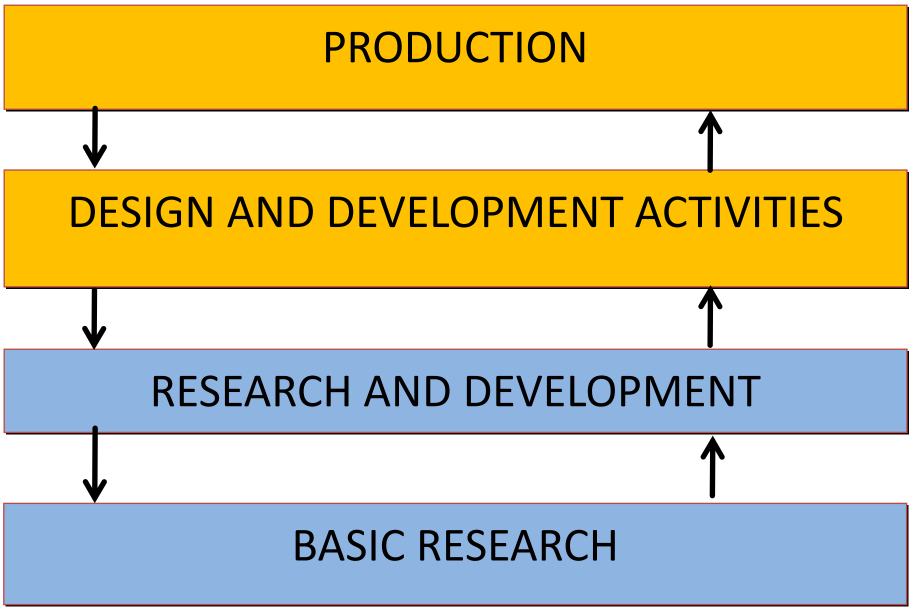

Figure 6. The technological innovation model for managing industrial R&D.
Source: Mahdjoubi D.: Holistic Model of Innovation: An innovation model for the real world.
https://www.ischool.utexas.edu/~darius/07-Holistic-model.pdf

An important role in this model is played by research and development as well as basic research. The Industrial Research and Development R&D centres, the main source of comprehensive industrial information for specific subjects, perform a wide range of activities, for instance:

- Preparation of standards and norms
- Preparation of tables and norms for the specifications of various materials
- Initiation of new information and know-how for various processes and production activities
- Study and proposal of new methods of management
- Study of various procedures for increasing productivity
- Development of new quality-control methods

The output of the R&D centres, i.e. comprehensive information about specific subjects, comes in different forms, such as tables, curves, graphs, formulas and computer software. The information and knowledge prepared by the R&D centres should be directed at specific and applied subjects.
As an extension of research, as in R&D, development implies reducing new knowledge to practice - verifying and validating experimental results and theoretical predictions, exploring specific cases, determining the accuracy and limits of mathematical models and methods.
To perform their duties, R&D centres require input information, which may be classified as "comprehensive information about general subjects" or briefly "scientific information".
Scientific information is very theoretic and cannot be used directly by industrial production units or D&D firms. In an ideal case, the scientific information is in the form of mathematical formulas, but the scientific information may also be found in the form of graphs, curves, tables, etc. Fundamental (Basic) Research Centres are the main generators of scientific information.[6]
The technological innovation model can be particularly helpful in cooperation with the industry at the level of basic research as well as research and development activities. Laboratories participating in ENSAR2 can provide research facilities for enterprises seeking research sources for new solutions and innovative products and processes.

The Crystal Clear Collaboration and CERN in medical applications – case study
Particle physics technologies are critical to many essential medical applications. State-of-the-art techniques borrowed from particle accelerators and detectors are increasingly being used in disease prevention, diagnosis, therapy and prognosis.

The Crystal Clear Collaboration (CCC) has found a way to scale down the scintillation techniques used in the powerful CMS detector at CERN to develop PET scan instruments that could be used to study brain activity in rats and mice. An initiative from Portugal called ClearPEM exploits the same scintillating crystals to detect breast cancer more effectively. One woman in eight will develop breast cancer: early detection saves lives. The technique promises to be five times as sensitive as conventional x-ray mammography, and to reduce the number of "false positive" finds that so often lead to unnecessary biopsies and to real human distress.

In a separate approach, calorimetry developed for particle detection is being deployed in the battle against pancreatic cancer: the massive detector technology designed to record the energy of 600 million collisions a second has been turned into something that can detect single photons of light in three dimensions and make ultraprecise images of biomarkers in, for example, a nascent tumour. Therefore, instead of putting a patient in a scanner, doctors can insert a tiny scanner inside the patient. It took 60 scientists, 13 institutes, €6 million and four years to turn the biggest detector in the world into one of the smallest and most precise. The technology delivered by the Endo-TOFPET-US project (an acronym that includes endoscopy, positron emission tomography, ultrasound and the technique called time-of-flight) will be 100 times more sensitive than a whole body PET scanner. CERN is a partner in CERIMED – a European centre for medical imaging bringing together research laboratories, companies and clinical partners – that will take the technology further.

However, there are other ways to use the precision dictated by the needs of the LHC experiments. The new detector technologies could help surgeons and clinicians see in ever finer detail and with greater clarity. It could even throw light on some forms of blindness. Think of the human eye as a kind of pixel detector: one collaborator in CERN's ATLAS experiment has turned a system originally designed to look for top quarks into a way of studying how the retina converts signals from photoreceptors and transmits them to the visual cortex. There are 22 or more different types of ganglion nerve cells in the retina that can now be monitored experimentally with a tiny "neurochip" first devised for particle physics. Another team has found a way to exploit colour-computerised tomography to reveal three-dimensional structure and resolve images of objects inside objects. The latest generation Medipix3 detector can distinguish elements that normally appear white: it can tell calcium in the bone from iodine by supplying colour based on differing wavelength responses. This LHC detector technology (as it once began) can now characterise pharmaceuticals, and even detect counterfeit drugs.

One scanner based on the Medipix advances can even distinguish two or more contrast agents in a patient at once – iodine in the vascular system and barium in the liver, for instance. Since it came on the market from New Zealand in 2009, MARS, the Medipix all resolution system CT scanner has been used to study cancer, heart disease and blood vessel breakdown.

The Neurospin project is designed to take magnetic resonance imaging to once-unimaginable precision: the study of the nervous system itself, and beyond that, the cruel neurodegenerative diseases that claim so many lives. It exploits detector technology that grew initially out of CERN and then out of French Atomic Energy Commission expertise.[5]

1.6 Recommendations regarding network cooperation between scientific units and industry

- Transfer of technology and knowledge through licensing agreements and know-how from the ENSAR2 project to industry in the area of basic research, research and development.
- Future cooperation with main actors from nuclear industry on the basic research level, research and development level. The most recommended fields of cooperation are reactor technology, nuclear safety, nuclear fuel cycle and decommissioning.
- Future cooperation with companies from medical sector – radioisotopes, radio pharmacy, medical devices.
- Future cooperation with companies, which produce tools and equipment for nuclear science.
- Active IP asset management of the laboratories' IP portfolio – matching technologies with innovative (internal or external) innovation models to add value to IP.
- Participation in brokerage meetings with the participation of enterprises in the area of basic research, research and development activities, design and development activities, production.
- Identification of enterprises from the end-user set and establishing cooperation with them as the main actors of the commercial network.

- Actions aimed at identifying and cooperating with SMEs at the levels of activity of basic research, R&D, design and development, production. These activities are to focus on the creation of an international network of SMEs in the field of nuclear physics. An important aspect in creating this network will be the regional activities of the centres participating in the project. Established regional contacts with SMEs will enable ENSAR2 participants to transfer them to the international network. The element connecting the network will be cooperation based on offers and queries in the areas of research and development, design, development and production.
- Cooperation with industry based on an open innovation model.
- Various forms of cooperation in production with business partners (commissioning of production, co-production, construction of complete research tools and devices).
- Undertaking activities aimed at developing a database of queries from the commercial sector in the field of basic research, development and research, development and production activities in the area of training, workshops, audits, technological audits, conducting expertise, implementation of projects aimed at development of products and processes.
- Distribution of catalogues (in paper and electronic form) promoting laboratories that participate in ENSAR2.
- Promotion of the NUPIA website on which the profiles of laboratories participating in the ENSAR2 project are located.
- Strengthening cooperation with organisations participating in the projects of the European Atomic Energy Community in the area of research development and techniques in the field of nuclear physics as well as in the area of training of experts and specialists.

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