Social and Economic Impact Assessment of the RCA Programme

Non-destructive Testing Case Study

IAEA Technical Cooperation Programme

RCA

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Acronyms

Name	Acronym
Asia Pacific Federation for NDT	APFNDT
Eddy Current Testing	ET
International Atomic Energy Agency	IAEA
International Committee for Non-destructive Testing	ICNDT
Multilateral Recognition Agreement	MRA
Magnetic Testing	MT
National Certification Body	NCB
Non-Destructive Testing	NDT
Liquid Penetrant Testing	PT
Quality Assurance	QA
Quality Control	QC
Radiographic Testing Method	RT
Regional Cooperative Agreement for Research, Development and Training related to Nuclear Science and Technology for Asia and the Pacific	RCA
Time of Flight Diffraction	TOFD
Ultrasonic Testing	UT

Executive Summary

The Regional Cooperative Agreement for Research, Development and Training related to Nuclear Science and Technology for Asia and the Pacific (RCA) will celebrate its 50th Anniversary in 2022. This report assesses the social and economic impacts of non-destructive testing (NDT) projects under the RCA, focusing on value added over and above the primary research that has been undertaken by individual countries independently.

NDT techniques are used in industry to evaluate the integrity and properties of material or components without causing damage to the tested object – for example, to detect defects and flaws in concrete components, welds in gas and water pipelines, storage tanks, and structural elements. NDT is a key tool for quality control, safety and reliability. Through RCA projects, regional training courses, workshops, expert missions and basic equipment in relation to nuclear NDT techniques have been provided to State Parties.

This impact assessment was designed and undertaken by a team of external experts, in consultation with IAEA and RCA stakeholders.[1] It involved gathering evidence through an online questionnaire completed by 20 of the 22 participating State Parties, analysis of IAEA administrative data, gathering information from NDT experts at the IAEA and State Parties, narrative success cases of NDT projects from four State Parties and economic analysis of costs and benefits of NDT projects under the RCA.

The impact assessment found that the RCA has contributed to strengthening NDT capacity and capability in the participating State Parties over the past 20 years. It has increased the scope and scale of the demand for and use of NDT leading to improved health and safety and economic value. These impacts include supporting State Parties to:

- Fulfil the Multilateral Recognition Agreement (MRA) requirements of the International Committee for NDT – including **82 per cent** of State Parties establishing a National Certification Scheme and **61 per cent** establishing a National Certification Body.
- Establish infrastructure to produce certified personnel in advanced and conventional NDT techniques – contributing to the certification of **2 807** personnel per year on average between 2000 and 2020.
- Become self-reliant in NDT, with **3 607** inspection centres and **191** firms offering training across the State Parties collectively, providing services to local industries as well as abroad.
- Increase awareness, interest and application of NDT technology for the quality assurance (QA) and quality control (QC) of industrial components in multiple industrial sectors including aerospace, chemical, construction, manufacturing, nuclear, oil and gas, petrochemical, power generation, railways and shipping – assuring material quality, product integrity, better controlled manufacturing and reduced production costs.
- Develop knowledge through R&D, including publishing **1 620** research articles and organising **4 300** international and national seminars and conferences.
- Improve health and safety by applying NDT technology in the industrial sectors.

1 The project was commissioned by the IAEA Technical Cooperation Division for Asia-Pacific (TCAP) and TC Division of Programme Support and Coordination (TCPC). Invited experts from the RCA programme provided advice and support. Please refer to the Acknowledgements for significant contributors.

These impacts are not solely attributable to the RCA, but State Parties indicated the RCA often contributed to each of these impacts to a great extent, including speeding up the adoption of NDT technologies, contributing to adoption of NDT technologies by private businesses and increasing the productivity of NDT inspections.

Cost-benefit analysis estimated that the RCA created more economic value than it consumed, with each EUR 1 of costs directly or indirectly attributable to the RCA between 2000 and 2020 associated with **EUR 1.20** of economic benefits on average across member states. Sensitivity analysis found that the net benefits attributable to the RCA remained positive under 63 per cent of alternative assumptions about drivers of benefits and costs, with a likely range of benefits between EUR 0.3 and EUR 3.7 per EUR 1 of costs. The estimates are conservative in that they only consider impacts on profits of firms that use NDT, and not wider societal benefits. Overall, this analysis indicates it is likely that the economic benefits of the RCA exceeded its costs.[2]

Pre-defined performance criteria were agreed with IAEA and State Party experts to provide an evaluative framework for the impact assessment (Tables 9–12, Annex G). On the basis of evidence provided by the IAEA and State Parties, the RCA's impacts meet standards for **good performance** in all four categories of impacts: improved NDT capacity and capability; increased scope and scale of NDT demand and use; improved health and safety; and economic value.

2 These results for the period 2000–2020 should not be used to make decisions about the future of the RCA or to decide whether the scale of the RCA should be increased or decreased.

Introduction

The International Atomic Energy Agency (IAEA) is the world's central intergovernmental forum for scientific and technical cooperation in the nuclear field. Established in 1957, and headquartered in Vienna, Austria, the IAEA works for the safe, secure and peaceful uses of nuclear science and technology, contributing to international peace and security and the United Nations (UN) Sustainable Development Goals. The IAEA works in close partnership with Member States, UN agencies, research organisations and civil society to maximise the contribution of nuclear science and technology to the achievement of development priorities ('Atoms for Peace and Development').

The Regional Cooperative Agreement (RCA) for Research, Development and Training Related to Nuclear Science and Technology for Asia and the Pacific (RCA) was established in 1972 and has enjoyed the benefit of the IAEA Technical Cooperation (TC) programme since. With the RCA due to celebrate its 50th Anniversary in 2022, it is timely to assess the social and economic impacts of the RCA supported under the IAEA TC programme.

22 **The RCA has 22 participating State Parties**

Australia	Laos	Philippines
Bangladesh	Malaysia	Singapore
Cambodia	Mongolia	South Korea
China	Myanmar	Sri Lanka
Fiji	Nepal	Thailand
India	New Zealand	Vietnam
Indonesia	Pakistan	
Japan	Palau	

At the 48th RCA General Conference Meeting in Vienna, Austria, 13 September 2019, the RCA endorsed the initiative to conduct social and economic impact assessments. To this end, the TC Division for Asia-Pacific (TCAP) and TC Division of Programme Support and Coordination (TCPC) jointly proposed to undertake case studies. A methodology was developed and was piloted to assess social and economic impacts of RCA projects. This report presents the findings from the social and economic impact assessment of non-destructive testing collaborations under the RCA.

Non-destructive testing

Non-destructive testing (NDT) techniques are used in industry to evaluate the integrity and properties of material or components without causing damage to the tested object – for example, to detect defects and flaws in concrete components, welds in gas and water pipelines, storage tanks and structural elements. NDT can identify cracks or flaws that might not otherwise be visible. These characteristics have made NDT a key tool for quality control, safety and reliability.

Aware of the significant social and economic benefits that are brought about by NDT techniques, the IAEA promotes the contribution of nuclear techniques to NDT to maintain the stringent quality control standards for the safe operation of nuclear and industrial establishments/installations.

To build and enhance capacity in NDT in RCA State Parties, regional training courses, workshops, expert missions and basic equipment in relation to NDT techniques have been provided through RCA NDT projects. As a result, the participating State Parties understand, absorb, receive, apply and develop the NDT techniques for the social and economic benefit of their countries and the region. In addition, many national NDT teams, training centres and certifying bodies have been established to provide services to industries. These efforts aim to support countries reaching a state of self-sufficiency in this area of technology.

Social and economic impact assessment methods

The social and economic impact assessment methodology was developed specifically for the IAEA, in order to conduct impact assessments for case studies of TC projects under the RCA. The methodology follows the *Value for Investment* approach (King, 2017; King, 2019; King & OPM, 2018) and the Kinnect Group approach to evaluation rubrics (King et al., 2013; McKegg et al., 2018) – combining evidence from quantitative, qualitative and economic analysis, through the lens of an agreed performance framework, to evaluate the impact of NDT projects under the RCA.

Social and economic impacts of the NDT projects are diverse and include contributing to a chain of impacts (see theory of change, Annex G) that includes:

- Establishing NDT infrastructure
- Producing certified personnel in NDT
- Raising awareness of NDT benefits for production quality, efficiency, and safety and
- Strengthening local and regional capability in industrial application and R&D leading to
- Improved productivity, quality and lower cost across industries
- Improved health and safety.

Some of these impacts can be evaluated using cost-benefit analysis. Our analysis focused on economic activity, using changes in the profits of firms that provide NDT services to clients or use NDT in-house to estimate the impacts of the RCA. Wider economic benefits from improved health and safety, self-reliance in NDT and ongoing R&D may also be significant but could not be estimated from available data as these are dispersed across many industries and applications of NDT.

Accordingly, the NDT case study uses a mix of methods and examines evidence from multiple sources, including:

- An online questionnaire deployed to all countries in the RCA and completed by 20 of the 22 State Parties
- Analysis of administrative data on NDT activity and costs, provided by IAEA
- Gathering additional information from NDT experts at the IAEA and State Parties
- Narrative case examples, written from details provided by four countries on a selection of 'success cases' of NDT
- Economic analysis of costs and benefits of the RCA's contribution to growing NDT capability and use in member states.

To combine the quantitative, qualitative and economic analysis, evaluation rubrics were developed. These rubrics, comprising a matrix of agreed criteria (aspects of performance) and standards (levels of performance) provided a transparent and robust framework for rating the social and economic impact of the NDT projects under the RCA from the mix of evidence. Refer to Annex G for full details of the methodology.

Social and economic impacts

The RCA has successfully supported participating State Parties in the Asia and the Pacific region to undertake a considerable body of work to grow NDT capacity and use. This impact assessment focuses on the most recent two decades, since the year 2000. It focuses on the value added by the RCA, over and above the growth that may have occurred within the individual countries if the RCA did not exist.

Key impacts of the RCA include its contributions to improved NDT capacity and capability, increased scope and scale of NDT demand and use, improved health and safety and economic impacts. The impacts are summarised in this section and detailed in a series of Annexes.[3]

A total of 22 State Parties participates in the RCA. Of these, 18 received support to accelerate their application of NDT in a safe, secure, effective and efficient manner. Four State Parties (Australia, Japan, New Zealand and South Korea since 2010) volunteered to work as resource countries to provide support for the TCP. The following analysis focuses on the State Parties that have received support through the programme.

Improved non-destructive testing capacity and capability

Under the RCA, technical cooperation has supported State Parties to:

Fulfil the Multilateral Recognition Agreement (MRA) requirements of the International Committee for Non-Destructive Testing (ICNDT)

Establish infrastructure to produce certified personnel in advanced and conventional NDT techniques

Become self-reliant in NDT, including offering training and inspection activities to local industries as well as abroad.

Significant progress has been made to **fulfil the MRA requirements of ICNDT.** Of the 18 State Parties that received support through the RCA:

- **16** have established a National Certification Scheme (NCS)
- **15** have registered their NDT Societies in the Asia Pacific Federation for NDT (APFNDT)
- **11** have established a National Certification Body (NCB) and 8 of these have been accredited to the ISO 17024 Standard[4]

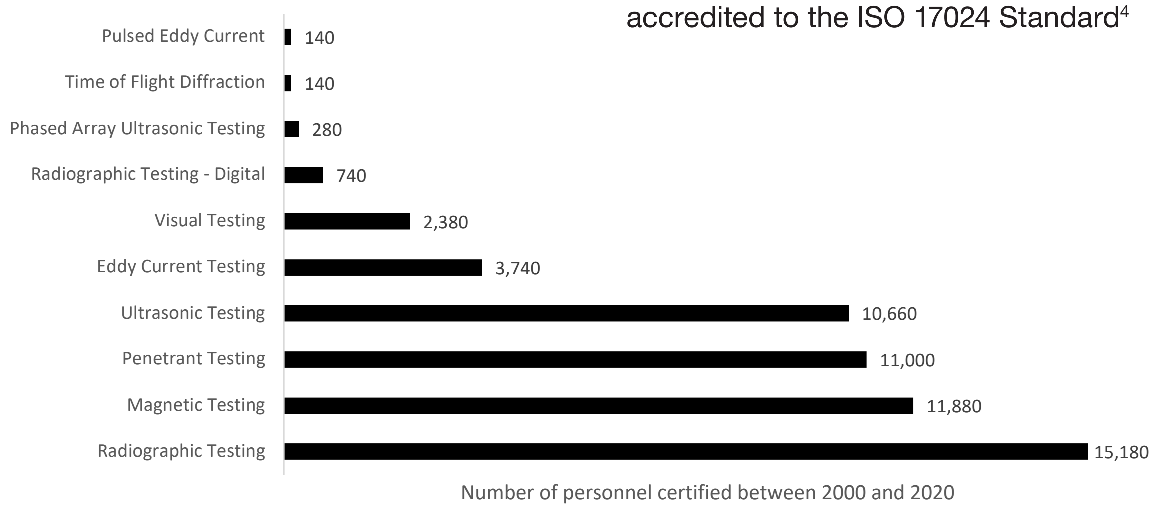


Figure 1: Personnel certified in NDT conventional and advanced techniques 2000 to 2020

3 For additional detail on these impacts, refer to Annexes A–D (case examples: Malaysia, Pakistan, Philippines, Sri Lanka), Annex E (survey results) and Annex F (economic analysis).

4 https://www.iso.org/standard/52993.html

Feedback from State Parties indicates that the RCA contributed significantly to these results. Furthermore, establishing NDT infrastructure has enabled State Parties to produce **certified personnel** in conventional and advanced nuclear NDT techniques. From 2000 to 2020, the RCA has contributed to the certification of **56 140 personnel** from 2000 to 2020 by local NDT Accredited Training Centres in 15 countries. The RCA contributed most significantly to certification in conventional nuclear NDT techniques (Figure 1).[5]

From the total certified personnel, 10.3 per cent were female. Efforts are ongoing to encourage the participation of more women in NDT training and certification.

Self-reliance in NDT is a function of countries having capacity to conduct inspections and train personnel without depending on external stakeholders. Collectively there are **191 training centres** and at least **3 607 inspection companies** owned by local firms across the State Parties that participate in the RCA.

15 State Parties have local inspection companies and **11** offer inspections abroad

14 State Parties have local training centres and **5** offer training abroad

According to State Parties, the RCA contributed to a great extent in the establishment of training centres in 12 countries and inspection centres in nine countries.

Increased scope and scale of non-destructive testing demand and use

The RCA programme on NDT has contributed to increased demand for NDT in the countries surveyed. In particular, the RCA has contributed to:

- Increased awareness, interest and application of NDT technology in industrial sectors for the quality assurance (QA) and quality control (QC) of industrial components
- Development of knowledge through R&D by publishing research articles, organising international and national seminars and conferences.

NDT has been applied in all recipient countries. Through the application of NDT technology, improvements have been

Pakistan is an example of how the RCA contributes to improved NDT capacity and capability in the country. Collaboration under the RCA in the area of NDT has contributed significantly to the establishment of Pakistan's national certification scheme, the registration of the NDT society with the APFNDT and accreditation to the ISO 17024 Standard of the national certification body.

Through participation in a series of regional NDT projects under the RCA, technical personnel were trained and certified on NDT by foreign institutions. The certified personnel then returned to Pakistan to deliver NDT training, design and implement courses on advanced NDT methods and contribute to the development of a national certification scheme. As a result, the National Centre for Non-Destructive Testing (NCNDT) is now conducting more than 20 NDT trainings with an average 200 trainees per year. Pakistan has inspection companies serving industries locally and abroad.

5 Conventional nuclear NDT techniques include Radiographic Testing (RT), Ultrasonic Testing (UT), Magnetic Testing (MT), Penetrant Testing (PT), Eddy Current Testing (ET), and Visual Testing (VT). Advanced techniques include Radiographic Testing – Digital (RT-D), Phased Array Ultrasonic Testing (PAUT), Time of Flight Diffraction (TOFD), and Pulsed Eddy Current (PEC).

achieved in terms of better controlled manufacturing, ensuring material quality, product integrity and production costs. **Positive impacts have been achieved in multiple sectors** including aerospace, chemical, construction, manufacturing, nuclear, oil and gas, petrochemical, power generation, railways and shipping (Figure 2).

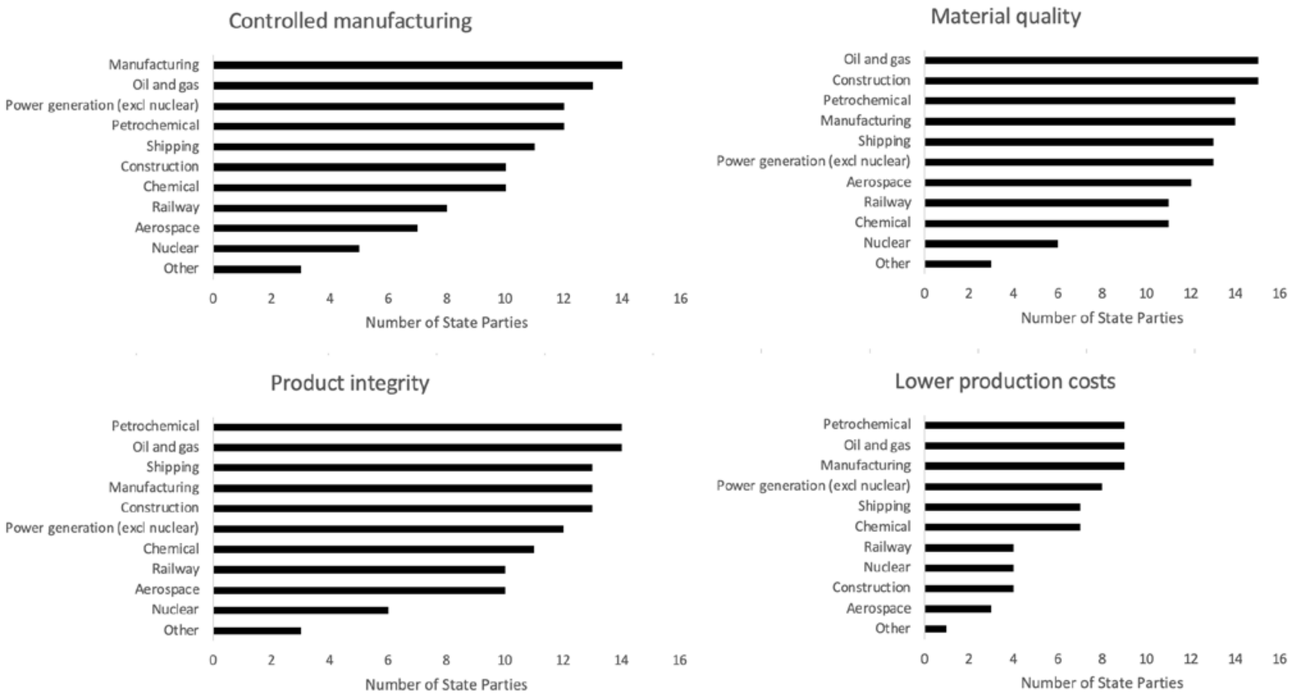


Figure 2: Improvements in controlled manufacturing, material quality, product integrity, and production costs by sector

For example, Malaysia has significantly increased awareness, interest, application and knowledge of NDT with the support of the RCA. NDT has been applied in nine industrial sectors in Malaysia, in particular the oil and gas sector, as well as power plants, shipyards and the aviation industry. The most important and widely used NDT technique in the Malaysian industrial market is radiographic testing to ensure material quality and product integrity.

The availability of high-quality NDT services at a competitive price enabled Malaysia to reduce the overall costs of NDT inspections, which in turn contributed to the development of the local industry.

Growth in local NDT training and inspection companies, together with the increasing demand for NDT services, has improved the employment prospects of graduates and other technical staff with expertise in NDT.

Through its participation in the RCA NDT programme, Malaysia has transformed from being dependent on foreign expertise to becoming self-reliant in NDT technology. The RCA contributed directly to the establishment of a national NDT infrastructure and the creation of a pool of local NDT experts, which in turn has contributed to the establishment of local NDT companies and training centres.

The RCA has contributed to significant knowledge dissemination through R&D. Of the 18 recipient State Parties involved in the RCA, **17** countries have trained people under the RCA and **12** have established R&D activities. Among these countries over the last 20 years:

1 620 publications related to NDT have been disseminated

4 300 seminars/conferences have been held

Improved health and safety

The RCA has enabled State Parties to improve health and safety by applying NDT technology in the industrial sectors. Of the 18 recipient State Parties, 17 reported that participation in the RCA had resulted in the application of NDT for safer operation of nuclear and other industrial installations. However, all but two State Parties were unable to provide estimates of the reductions in chemical waste, reduced injuries or reduced deaths.

Sri Lanka, for example, reported that being part of the RCA NDT programme has contributed to increased awareness about the application of NDT technologies for safer operations within industrial installations. The RCA has promoted best practices and triggered the emergence of an NDT testing culture among industrial companies, paving the way to a safer workplace.

Overall impact of the RCA on NDT adoption

Feedback from the State Parties involved in the RCA indicates that the RCA has impacted on the adoption of NDT technology in several ways. As shown in Figure 3, among the 18 recipient State Parties:

- **15** reported the RCA had helped to speed up the adoption of NDT technologies
- **14** reported the RCA had contributed to the adoption of NDT technologies by private businesses
- **11** reported the RCA had helped increase the productivity of NDT inspections (reducing the average time to complete an inspection).

	Nepal	Australia	Cambodia	Japan	New Zealand	Myanmar	Indonesia	Laos	Mongolia	Bangladesh	India	Malaysia	China	Pakistan	Philippines	Singapore	Thailand	Vietnam	South Korea	Sri Lanka
RCA help speed up adoption						1-3 yr faster	1-3 yr faster	1-3 yr faster	4-5 yr faster	1-3 yr faster	1-3 yr faster	1-3 yr faster	4-5 yr faster	4-5 yr faster	4-5 yr faster	4-5 yr faster	4-5 yr faster	4-5 yr faster	+6yr faster	+6yr faster
RCA help private business adoption							Up to 25%	Up to 25%	51 to 75%	51 to 75%	Up to 25%	Up to 25%	Up to 25%	Up to 25%	51 to 75%	51 to 75%	25 to 50%	25 to 50%	25 to 50%	Up to 25%
RCA increased productivity										10 to 20%		10 to 20%	Up to 10%	10 to 20%	10 to 20%	10 to 20%	+20%	10 to 20%	+20%	10 to 20%

Contribution of RCA in achieving general objectives

N/A ▪ No ▪ Yes

Data: IAEA's NDT online survey, 2021

Figure 3: Contribution of RCA activities in achieving general objectives and benefits for State Parties

In the Philippines, through participation in the NDT programme of the RCA, the national industrial sector has increased its knowledge and understanding of the advantages of using NDT technology for quality assurance and quality control processes. This increased knowledge and understanding, together with the greater availability of locally certified NDT personnel and local NDT inspection companies, has resulted in the increased adoption of NDT for industrial testing in several industrial sectors, particularly in the oil and gas, power generation, aerospace, and shipping sectors.

It is estimated that the RCA has contributed between half to three-quarters of private business adoption of NDT technology, leading these businesses to adopt NDT 4–5 years more rapidly than they otherwise might have. With this wider adoption of NDT technology, industries are experiencing more reliable operations, and this is translating into an estimated 10–20 per cent increase in productivity.

Furthermore, RCA NDT training has contributed to the promotion of improved practices in the application of NDT technologies resulting in safer operations within industrial installations.

Economic impacts

A social cost-benefit analysis was conducted to estimate economic impacts from capacity building and adoption of NDT generated by the RCA. The analysis estimated the incremental (additional) costs and benefits that are attributable to the RCA – it did not estimate the benefits and costs of NDT activities as a whole but rather the benefits and costs associated with technical cooperation under the RCA, compared to a hypothetical situation with no RCA.

The analysis used data from the survey, together with administrative and cost data provided by the IAEA, and public data from other sources. It estimated the costs and benefits that occurred between 2000 to 2020. Costs and benefits were analysed as annual time series and adjusted for timing, using discounting to convert values occurring at different points in time into present values.

Benefits reflect the more rapid adoption of NDT and expansion of NDT activity in the private sector attributable to the RCA. As these benefits cannot be measured directly, the analysis estimates impacts of accelerated adoption of NDT on profits of firms that provide NDT services to customers or that use NDT in-house.

Costs represent the opportunity costs arising from committing resources of the IAEA and RCA state parties to RCA-related activities. They include costs directly associated with RCA activities, in-kind (non-monetary) contributions of State Parties to support RCA activities, and the portion of capital costs associated with expanded NDT adoption in RCA State Parties that can be attributed to RCA activities.

Results of the analysis indicate that the RCA delivered good economic outcomes, with estimated benefits exceeding estimated costs in most scenarios that we tested. In the baseline scenario, it was estimated that the RCA NDT activities between 2000 and 2020 generated **EUR 1.2 of economic benefits** on average for each EUR 1 of costs (valued in 2020 EUR).

As is often the case in cost-benefit analysis, some important parameters required modelling assumptions to be developed, in consultation with NDT experts. To understand the implications of uncertainty in these modelling assumptions, sensitivity analysis was conducted that involved testing how the estimates of benefits and costs varied under alternative assumptions. Sensitivity analysis revealed that under a range of alternative assumptions, **benefits could be between EUR 3.0 and EUR 3.7 for each EUR 1 of costs on average.** The ratio of benefits to costs was greater than 1 (i.e. break-even was achieved) in 63 per cent of scenarios tested. These estimates are conservative in that they include most, but not all benefits associated with greater use of NDT. For example, benefits to buyers of NDT services and society more generally were not included in this analysis. In our assessment, the investment in the RCA NDT programme by IAEA and State Parties more likely than not generated more value than it consumed.

These estimates of costs and benefits are retrospective and are based on actual outcomes under the RCA between 2000 and 2020 versus what we estimate would have happened in the absence of the RCA in that period. These results should not be used to make decisions about the future NDT-related activities under the RCA or to decide whether their scale should be increased or decreased. Full details of the cost-benefit analysis are provided in Annex F.

Conclusion

The RCA has supported significant gains in NDT capacity and use through speeding up adoption of NDT technologies and contributing to adoption of NDT technologies by private businesses. Significant economic and social value has been generated through these gains.

Cost-benefit analysis estimated that the RCA on balance of probabilities created more economic value than it consumed between 2000 and 2020, with each EUR 1 of costs incurred between 2000 and 2020 associated with an estimated EUR 1.2 of economic benefits.

Pre-defined performance criteria were agreed with IAEA and State Party experts to provide an evaluative framework for the impact assessment (Tables 9–12, Annex G). Overall, the evidence of RCA impacts provided by the IAEA and State Parties indicates that the RCA meets agreed standards for **good performance** in achieving its intended impacts across all four impact domains: improved NDT capacity and capability in the participating State Parties; increased scope and scale of demand, for, and use of NDT; improved health and safety; and economic value.

Annex A: Non-Destructive Testing in Malaysia under RCA – case example

Background

Malaysia started using NDT for quality assurance and quality control processes in the industrial sector in the early 1960s. At that time, this mainly meant the application of Radiographic Testing techniques in the power generation sector. When the national petroleum company, Petronas, was formed in 1974, the country started to experience wide scale demand for NDT technology, particularly to support the development of the oil and gas sector.

During these first decades of NDT development, Malaysia was highly dependent on foreign NDT providers and certified NDT personnel hired from abroad. This made NDT activities very expensive and meant that Malaysia's industrial sector was dependent on foreign workforce and expertise. Involvement of local personnel was minimal, limited to providing assistance to foreign experts throughout the inspection activities. The first local NDT company was formed in 1975, but there were few local certified personnel available. This was due to the fact that local personnel had to travel abroad to get qualified and certified, which was costly and ultimately discouraged many from getting NDT certified.

It was not until 1981 that Malaysia became part of the NDT programme under the Regional Cooperative Agreement for Research, Development and Training Related to Nuclear Science and Technology for Asia and the

Malaysia's national NDT certification scheme received recognition by ICNDT and registered for MRA. Source: Nuklear Malaysia

RCA regional training course on Digital Radiographic Testing hosted by Nuklear Malaysia in 2017. Source: Nuklear Malaysia

Pacific (RCA). Since then, participation in the RCA NDT programme has helped Malaysia's Nuclear Agency (Nuklear Malaysia) establish and develop NDT capacity in the country. The RCA NDT programme has provided assistance for the development of a national certification system and supported the development of NDT facilities as well as the provision of expertise and training resources.

Establishment of NDT infrastructure

The Malaysian Skills Certification System for NDT (SPKM-NDT) was initially introduced in 1986 as a direct result of participation in the RCA NDT programme. The SPKM-NDT certification scheme was an initiative by the Department of Skills Development (DSD) to ensure work processes and quality control in certifying NDT personnel are in accordance with international practice. The implementation of the SPKM-NDT certification is based on the international standard ISO 9712. The DSD is the sole national certification body (NCB) for the scope of NDT obtaining ISO 17024: 2012. This certification body is also registered under the International Committee for Non-destructive Testing (ICNDT) Multilateral Recognition Agreement (MRA).

Malaysia also received RCA support for the establishment of their NDT Society in 1989. The society currently has 687 registered professional members including researchers, service providers, equipment suppliers, plant and asset owners and academia, among others. The NDT Society's broad and diverse membership plays an important role in the promotion and uptake of NDT technology in the country.

In the early years of involvement in the RCA NDT programme Malaysia started to train and certify NDT personnel locally. Some of these experts, encouraged by the increasing demand of NDT technology in the country, soon contributed to the establishment of local NDT inspection companies and training centres.

45 114

Between 2000 and 2020, the number of local NDT inspection companies increased from 45 to 114

13 out of the **15** NDT training centres are local and accredited under the NCB.

Certification of personnel on NDT

In 1986, Nuklear Malaysia, in collaboration with DSD and the Atomic Energy Licensing Board (AELB) conducted the first NDT training course in Radiographic Testing. Since this first national training course, the RCA NDT

The first qualification examination for Digital Radiographic Testing under the Malaysian certification scheme conducted in 2020.
Source: Nuklear Malaysia

programme has helped to develop local expertise by organizing training courses and scientific visits and supplying equipment. As a result, Malaysia has gone on to produce a cohort of qualified and certified NDT personnel able to perform NDT activities for local industries. It is estimated that between 2000 and 2020, almost 180 individuals were trained yearly under the RCA NDT programme.

Certifications in Radiographic Testing, Ultrasonic Testing, Magnetic Testing, Penetrant Testing and Eddy Current Testing were introduced under the RCA NDT programme prior to 2000. After 2000, Digital Radiographic Testing certification was introduced by the RCA. Creating awareness and sharing basic understanding regarding this NDT technique was the focus of early RCA projects. In 2017,[6] the first regional training course under the RCA NDT programme was conducted leading to official certification in Digital Radiographic Testing. A second regional training was conducted using a similar format in 2019.[7] Malaysia then successfully conducted its own Digital Radiographic Testing training and examination in 2020, and the first group of participants from the course received their official certification in 202.

It is estimated that between 2000 and 2020, almost 180 individuals were trained yearly under the RCA NDT programme.

6 Under RAS1020, ‘Building Capacity for Applications of Advanced Non-Destructive Evaluation Technologies for Enhancing Industrial Productivity (RCA)’

7 Under RAS1022, ‘Strengthening Regional Capacity in Non-Destructive Testing and Examination Using Nuclear and Related Techniques for Safer, Reliable, More Efficient and Sustainable Industries Including Civil Engineering (RCA)’

Adoption of NDT technology

Industrial testing using NDT technology has been widely adopted in Malaysia since the early 1980s, mainly within the oil and gas sector. Companies in this sector account for around 70 percent of all NDT inspections in the country. Power plants, shipyards and the aviation industry are other important clients that often benefit from this technology.

The most important NDT technique and most widely used in the Malaysian industrial market is Radiographic Testing. The main benefits of this technique are related to the maintenance of materials and structures, ensuring material quality and product integrity without causing any damage or leaving any radioactive residue.

Social and economic effects

Through its participation in the RCA NDT programme, Malaysia has transformed from being dependant on foreign expertise to becoming self-reliant in NDT technology. RCA contributed directly to the establishment of a national NDT infrastructure and the creation of a pool of local NDT experts, which in turn has contributed to the establishment of local NDT companies and training centres.

The availability of high-quality NDT services with a competitive price enabled Malaysia to reduce the overall costs of NDT inspections, which in turn contributed to the development of the local industry, mainly in the oil and gas sector. Furthermore, the larger number of local NDT training and inspection

Local NDT inspector performing inspection on industrial component. Source: Nuklear Malaysia companies, together with the increasing demand of NDT services, has improved the employment prospects of graduates and other technical staff with expertise in NDT.

Finally, the establishment of an internationally recognized NDT certification scheme improved safety and contributed to the optimized operation of industrial plants through standardized inspection practices.

Through its participation in the RCA NDT programme, Malaysia has transformed from being dependant on foreign expertise to becoming self-reliant in NDT technology.

Annex B: Non-Destructive Testing in Pakistan under RCA – case example

Background

Pakistan started using NDT for quality assurance and quality control processes under the direction of the Pakistan Atomic Energy Commission (PAEC) in 1974. At that time, there was little awareness of the benefits of using NDT for quality assurance and quality control processes, and the application of these techniques in the industrial sector was still minimal. Qualified NDT personnel were also rarely available from within the country. In 1983 Pakistan became part of the NDT programme under the RCA, which greatly contributed to developing NDT capacity in the country.

Collaboration under the RCA contributed to the establishment of the National Centre for Non-Destructive Testing (NCNDT) under the PAEC in 1986. The NCNDT's aim was to respond to the slowly increasing local demand for NDT services. During the initial years of operation, experienced engineers, scientists and other technical staff of the NCNDT benefited from technical education and training in NDT techniques through their participation in regional projects under the RCA. Since then, the RCA NDT programme has continuously provided the country with expertise, training and resources in the most advanced NDT techniques. It has also contributed to raising awareness and encouraging the adoption of NDT technology among the local industry.

Establishment of NDT infrastructure

The RCA NDT programme also contributed to the development of a national NDT certification scheme in Pakistan. Through participation in a series of regional RCA NDT projects, technical personnel of the NCNDT were trained and certified on NDT techniques by foreign institutions. With the knowledge and experienced gained through this collaboration, these certified personnel then returned to Pakistan to deliver NDT training. They designed and implemented courses on advanced NDT methods and contributed to the development of the national certification scheme. In 2020, the NCNDT was accredited as a personnel certification body for NDT by the Pakistan National Accreditation Council (PNAC), an institution under the administrative control of the Ministry of Science and Technology. The NCNDT became the first personnel certification body accredited as per standard ISO 17024:2012 in Pakistan.

In addition to training activities, the NCNDT started offering NDT services to both PAEC establishments and the local industry during manufacture and fabrication, as well as pre-service and in-service inspections. Some of the national experts certified under the RCA NDT programme, attracted by the increasing demand of NDT services among the local industry, also contributed to the establishment of additional training centres and NDT inspection companies. Between 2000 and 2020, three additional local NDT training centres were created, and the number of local NDT inspection companies doubled from 3 to 6.

Between 2000 and 2020, three additional local NDT training centres were created, and the number of local NDT inspection companies doubled from 3 to 6.

Finally, collaboration under the RCA NDT programme contributed to the establishment of the Pakistan Society for NDT (PASNT) in 1995, which today has 250 professional members. The main goal of PASNT is the development and promotion of NDT technology in the country.

Lecture on radiation safety is in progress organized by NCNDT, Islamabad. Source: National Centre for Non-Destructive Testing

Certification of personnel on NDT

Under the work of the RCA NDT programme, Pakistan began participating in several NDT training courses at the regional level in the 1980s. The training was delivered with the intent of raising core groups of trainers who could later impart training and NDT certification in their respective countries and provide NDT services to their national industries. Today, the NCNDT is conducting more than 20 NDT training courses per year, and it is reported that between 2000 and 2020, almost 200 individuals were trained annually in NDT methods.

It is reported that between 2000 and 2020, almost 200 individuals were trained annually in NDT methods.

Prior to 2000, certification in Radiographic Testing, Ultrasonic Testing, Magnetic Testing, Penetrant Testing and Eddy Current Testing were introduced in Pakistan in collaboration with the RCA NDT programme. After 2000, Visual Testing was incorporated into the certifications available. Recently, courses on advanced NDT techniques such as Digital Radiographic Testing, Phased Array Ultrasonic Testing or Time of Flight Diffraction have been delivered through the RCA NDT programme, although no official certifications are yet available.

Certification examination is in progress at NCNDT, Islamabad. Source: National Centre for Non-Destructive Testing

Adoption of NDT technology

The RCA NDT programme also contributed to raising awareness and encouraging the uptake of NDT technology among the local industry. The RCA NDT programme has collaborated with the PASNT to organise seminars and conferences on the latest developments of NDT techniques to provide platforms for the sharing of best practices and promote enrolment into NDT training and certification programmes. As a result, NDT techniques are increasingly being used to improve and maintain the quality of manufactured goods as well as for proper and safer maintenance of industrial plants and equipment.

Typical industries that have benefitted the most from the application of NDT technology in industrial processes include oil and gas, power generation, petrochemical and manufacturing. Furthermore, the nuclear sector is highly advanced in the adoption of NDT technology for quality assurance and quality control of critical components of nuclear power plants (NPP), since stringent quality and regularity of NDT inspections helps the sector ensure safer and more reliable operations.

Social and economic effects

Through its participation in the RCA NDT programme, Pakistan generated a pool of local NDT experts who contributed to the development of a comprehensive national NDT infrastructure. This, together with an improved awareness about the benefits of applying NDT techniques in industrial processes, encouraged the use of NDT services among several industrial sectors. As a result, positive improvements have been achieved in terms of controlled manufacturing, lower production costs, better material quality and greater productivity in the sectors above.

Furthermore, the introduction of NDT technology in the nuclear sector has made a considerable contribution to ensuring safer operations of the country's NPPs. Nuclear safety is now a priority area for the country with thorough and exhaustive inspections of both existing and planned NPPs highly encouraged. NDT is used for inspections of piping systems, steam generators, coolant loops and other vital structural components, both during pre- and in-service inspections of the NPPs.

Penetrant testing of generator rotor blades at power plant Source: National Centre for Non-Destructive Testing

Annex C: Non-Destructive Testing in the Philippines under RCA – case example

Background

The Philippines started using NDT for quality assurance and quality control processes in the industrial sector in the early 1970s. At that time, the use of NDT technology for industrial processes was minimal and only a few experts had experience with it. Most industrial companies were not aware of the possibilities of applying NDT for industrial testing and a limited number of practitioners were undertaking NDT activities in the country. Among academia, NDT knowledge was not developed and university, colleges and even trade and engineering schools did not include it in their curricula.

In 1979, the Philippines joined a preparatory assistance project co-implemented by the United Nations Development Programme (UNDP) and the IAEA through the Philippine Atomic Energy Commission (PAEC). Part of the scope of this industrial project was NDT. A year later, in 1980, the Philippines officially became part of the NDT programme under the RCA. Through participation in the RCA NDT programme, the Philippines has become more self-reliant in NDT capacity. The programme has contributed to the establishment of national NDT infrastructure and the development of local NDT know-how, and it has triggered increased investment in NDT technology.

Establishment of NDT infrastructure

Due to the work of some PAEC leaders and other NDT practitioners through the UNDP/IAEA assistance project, the Philippine Society for NDT (PSNT) was established in 1979. Today, the society has around 1 000 professional members who represent stakeholders and practitioners in various sectors of the national industry. The PSNT hosts seminars, workshops and conventions for its members and external stakeholders to promote the latest developments in the field of NDT. Furthermore, in collaboration with the PAEC (now the Philippine Nuclear Research Institute or PNRI), the society conducts national training and certification programmes in NDT.

In 1982, the UNDP/IAEA assistance project developed into a full RCA industrial project[8] which extended to 1986, with a second phase[9] running from 1987 to 1991. In 1987, through the participation in this RCA NDT project, the PSNT established the National Certifying Body for NDT (NCB). This body had the responsibility to implement the national NDT certification scheme[10], compliant with ISO standards. In 2008, the NCB was re-organized as the Philippine National Certifying Body for NDT (PHIL-NCB-NDT).

2018 PSNT Annual Convention and General Membership Meeting. Source: Philippine Nuclear Research Institute

8 RAS79051

9 RAS86073

10 Standard PNS:146-1987 ‘Qualification and Certification of NDT Personnel’, later revised into PNS-146:1998, and currently PNS ISO 9712:2020, accredited to ISO 9712.

Graduates of Radiographic Testing training course conducted by PNRI and PSNT in 2016. Source: Philippine Nuclear Research Institute

Participation in the RCA NDT programme also contributed to the establishment of the Nuclear Training Centre under the PNRI in 1987. Since then, two additional local NDT training centres have been created, mainly through the work of graduates of the first PNRI-PSNT NDT training courses.

Finally, it is reported that between 2000 and 2020, the number of local NDT inspection companies increased from 20 to 30. Most of these private-sector firms are corporate members of the PSNT and are therefore aware of how providing NDT inspection services can ensure the quality and safety of their industrial products and components. Furthermore, the RCA NDT programme increased the national demand for NDT services, encouraging the private sector to venture in NDT inspection services.

Certification of personnel on NDT

The first RCA NDT training on Radiographic Testing – level 3 was conducted by international experts in the Philippines in 1986. A year later, this training was followed with a series of training for trainers on Ultrasonic Testing and Eddy Current Testing.

Between 2000 and 2020, the number of local NDT inspection companies increased from 20 to 30.

In addition to the international expertise, the NDT programme of the RCA provided the country with NDT equipment such as industrial X-ray machines, equipment for Ultrasonic Testing, Eddy Current Testing, Magnetic Testing, and Penetrant Testing and machinery for NDT testing of concrete.

From 1987, the Nuclear Training Centre under the PNRI, in collaboration with the PSNT, began offering regular NDT training courses on a wide range of methods[11], becoming the pioneer training institution for NDT in the country. More than 8 000 individuals were trained in the methods under the NDT programme of the RCA between 1986 and 2020.

Adoption of NDT technology

Through participation in the RCA, the national industrial sector has increased its knowledge and understanding of the advantages of using NDT technology for quality assurance and quality control processes.

11 Radiographic Testing, Ultrasonic Testing, Eddy Current Testing, Magnetic Testing, Penetrant Testing, and Visual Testing.

This increased knowledge and understanding, together with the larger availability of locally certified NDT personnel and local NDT inspection companies, has resulted in an increased adoption of NDT for industrial testing in several industrial sectors. The highest levels of adoption of NDT technology for quality assurance and quality control are in the oil and gas, power generation, aerospace and shipping sectors.

Many industries report having reduced their operating costs between 5 per cent and 10 per cent thanks to the introduction of NDT technology.

Social and economic effects

With the wider adoption of NDT technology among industrial sectors, the Philippines is experiencing more reliable operations of many industrial facilities. This is translating into higher productivity. Non-invasive procedures allow industries to check for material quality and product safety with less downtime, which eliminates the need to shut down operations during testing. As a result, many industries report having reduced their operating costs between 5 per cent and 10 per cent thanks to the introduction of NDT technology.

Furthermore, RCA NDT training has contributed to the promotion of improved practices in the application of NDT technologies resulting in safer operations within industrial installations.

Onsite NDT training at TSUNEISHI Shipbuilding facility in Balamban, Cebu in 2013. Source: Philippine Nuclear Research Institute

Annex D: Non-Destructive Testing in Sri Lanka under RCA – case example

Background

In 1982, Sri Lanka became part of the NDT programme under RCA. Before participating in the programme, the number of industrial organisations using NDT technology for quality assurance and quality control processes was limited to leading industrial organizations such as Ceylon Petroleum Corporation, Colombo Dock Yard and Sri Lankan airlines. Most NDT services in the country were provided by foreign companies and there were no training facilities or qualified local NDT personnel.

After joining the NDT programme of the RCA, the Atomic Energy Authority (AEA)[12], a statutory body under the Ministry of Power and Renewable Energy, became the main institution responsible for designing and implementing Sri Lanka's NDT programme. This included providing NDT inspection services to the industry and training and qualifying NDT personnel.

Establishment of NDT infrastructure

As part of joining the NDT programme of the RCA, Sri Lanka was required to establish an NDT Society, which was created in 1988. The society currently has over a hundred professional registered members. Since the start of its activity, the NDT Society has been responsible for developing and raising awareness about the importance of a local NDT programme in Sri Lanka among key stakeholders and policymakers.

With support from the RCA, the NDT section of the AEA also established a national NDT Certification Scheme and a Certification Body for NDT (CBNDT). The CBNDT was established in 2009 and it is registered under the International Committee for NDT (ICNDT) Multilateral Recognition Agreement (MRA).

Given the increasing importance of the national NDT programme, the Sri Lankan Government established the National Centre for NDT (NCNDT) in 2014, with a view to further promote the uptake of NDT technology in the country, support consistent technological development and improve productivity of the industry. The NCNDT is now the main NDT service provider in the country and provides NDT training and inspection services to government and private sector industries, as well as welder qualification and certification services. Since its creation, the NCNDT also facilitates the national CBNDT.

Certification of personnel on NDT

The NDT section of the AEA was responsible for training and qualifying NDT local personnel until 2013. With the establishment of the NCNDT in 2014, NDT training and qualification are now provided by the NCNDT. The NCNDT is accredited as the first personnel certification body of Sri Lanka as per the ISO 17024. Today, the training unit of the NCNDT can certify NDT personnel in Radiographic Testing, Ultrasonic Testing, Penetrant Testing, Magnetic Testing and Eddy Current testing at three levels of proficiency.[13]

Between 2000 and 2020, it is reported that almost 200 individuals (mainly quality assurance and quality control inspectors, technicians, welders, engineers and surveyors in the industrial field) **were trained yearly in the methods under the RCA NDT programme.** This was achieved mainly through the delivery of local and regional training and qualification courses and workshops.

12 The AEA was repealed in 2014 and substituted by the Sri Lanka Atomic Energy Board (AEB) and the Sri Lanka Atomic Energy Regulatory Council (AERC).

13 In accordance with ISO 9712:2012 Standard and the IAEA syllabi: IAEA TECDOC – 628/Rev.03, 'Training Guidelines in Non-Destructive Testing Techniques'.

Training on Ultrasonic Testing Level 1 (as per ISO 9712), conducted in July 2020 by the NCNDT. Source: National Centre for Non-Destructive Testing

Adoption of NDT technology

In addition to contributing to the establishment of NDT infrastructure and certifying local experts in NDT methods, the RCA NDT programme also increased the interest of industrial stakeholders in applying NDT technology for quality assurance and quality control processes by engaging with them through local exhibitions and forums. As a result, the application of NDT technology among industrial companies has become widespread in the country.

Those who have benefitted the most from the application of NDT technology in industrial processes are the power generation, aerospace, oil and gas, manufacture and shipping sectors, among others. In fact, some of the leading industries have established their own NDT inspection departments to cater their regular NDT compliance needs. For example, electricity providers fulfil regular NDT inspections which are often provided by the NCNDT itself.

Social and economic effects

As a result of applying NDT technology, positive improvements have been achieved in terms of controlled manufacturing, lower production costs, better material quality and greater productivity in the sectors above. For example, sectors such as oil and gas, power generation, manufacture and shipping report having moderately reduced their production costs due to the introduction of NDT technology between 2000 and 2020.

With the application of NDT technology, many industrial companies can maintain continuous operation without suffering unexpected shutdowns, as well as quickly identifying defective components, positively contributing to the competitiveness of the sector. Furthermore, official NDT certification is an added value for certain industrial products, particularly those commercialised in the foreign market, because it guarantees that a product has gone through certified quality assurance and quality control processes.

Being part of the RCA NDT programme has also contributed to increased awareness of the application of NDT technologies for safer operations within industrial installations. The RCA NDT programme has also promoted best practices and triggered the emergence of an NDT testing culture among industrial companies, paving the way to a safer workplace.

Ultrasonic Testing Inspection on Grantry Rails of East Container Terminals, Sri Lanka Ports Authority, by NCNDT Inspection Team in September 2020. Source: National Centre for Non-Destructive Testing

Annex E: Survey Analysis

Introduction

This Annex presents survey findings of the Social and Economic Impact Assessment of the RCA's contribution to NDT in the Asia and Pacific region. The data that informs the analysis was collected through an online survey that was designed and piloted in May 2021 and deployed between June and August 2021. The respondents to the survey were national experts on the field of NDT. They provided relevant information

Figure 4: Map of the 20 countries that participated in the online survey: Australia, Bangladesh, Cambodia, China, India, Indonesia, Japan, Laos, Malaysia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Thailand and Vietnam.

about the equipment, training centres, certified personnel and the health and safety impacts of the RCA in their country.

To understand the contribution of the RCA NDT programme on social and economic indicators, the study analyses the extent to which being part of the programme has enabled the State Parties to:

Improve NDT capacity and capability

- Fulfil the Multilateral Recognition Agreement (MRA) requirements of the International Committee for Non-destructive Testing (ICNDT) as a result of the support under the RCA NDT programme.
- Establish State Parties' NDT infrastructure to produce certified personnel in advanced techniques (Radiographic Testing – Digital, Phased Array Ultrasonic Testing, Time of Flight Diffraction, and Pulsed Eddy Current), in addition to the conventional methods (Radiographic Testing, Ultrasonic Testing, Magnetic Testing, Penetrant Testing and Eddy Current Testing).
- Achieve self-reliance in NDT, including offering training and inspection activities to local industries as well as abroad.

Increase scope and scale of NDT demand and use

- Enhance awareness, interest, and application of NDT technology in the industrial sectors for the quality assurance (QA) and quality control (QC) of industrial components.
- Develop knowledge through R&D by publishing research articles, organising international and national seminars and conferences.

Improve health and safety

- Improve health and safety by applying NDT technology in the industrial sectors.

It is worth mentioning that the IAEA Technical Cooperation Programme (TCP) has been established by the IAEA to support IAEA State Parties (especially developing countries) to accelerate and enlarge the application of nuclear technologies in a safe, secure, effective and efficient manner. In principle, every IAEA Member State can receive and enjoy the benefit of the IAEA TCP. However, some State Parties (especially developed/advanced countries) volunteer not to receive the IAEA TCP, but they work as resource countries to provide support for the IAEA TCP. Under the RCA, there are 22 countries of which 18 countries are TC recipients and 4 are TC non-recipients (Australia, Japan, New Zealand, and since 2010 South Korea). Based on this definition, the three countries that have historically acted as non-recipients (Australia, Japan and New Zealand) are excluded from the assessment of the criteria and level of performance conducted in this analysis. Given their historically non-recipient character, any assessment of the performance of RCA to accelerate and enlarge the application of NDT technologies in those countries would result in a misinterpretation of the results.

Pre-defined performance criteria were agreed with IAEA and State Party experts to provide an evaluative framework for the impact assessment (Tables 9–12, Annex G). Figure 5 summarises the performance of the RCA for each State Party against the defined criteria (aspects of performance) and standards (levels of performance). Note that these ratings apply to the performance of the RCA in contributing to social impacts in each country – they do not represent the performance of the individual countries.

The complete analysis for all the aspects of performance is presented in the next sections.

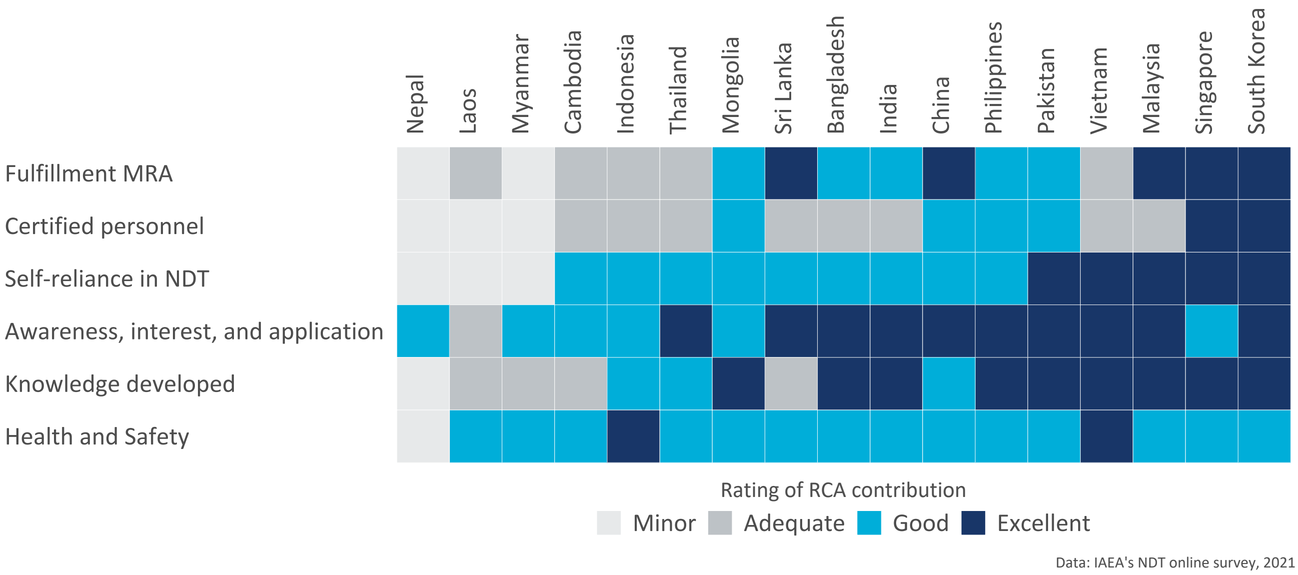


Figure 5: Rating of RCA contribution to social impacts by criteria and State Parties

Criterion 1: Improved NDT capacity and capability

To understand the contribution of the RCA NDT programme to developing the capacity and capability of the State Parties, this section presents the results of the assessment of the extent to which the support of the RCA NDT programme has enabled State Parties to:

- Fulfil the Multilateral Recognition Agreement (MRA) requirements of the International Committee for Non-destructive Testing (ICNDT) as a result of the support under the RCA NDT programme.
- Establish State Parties' NDT infrastructure to produce certified personnel in advanced techniques, in addition to the conventional methods.[14]
- Achieve self-reliance in NDT, including offering training and inspection activities to local industries as well as abroad.

Key results of this assessment are summarized in the below table.

Sub-criterion	Evidence	Finding
Fulfilment of MRA	Per cent of recipient State Parties that have established a National Certification Body	61%
Fulfilment of MRA	Per cent of recipient State Parties that have established a National Certification Scheme	82.3%
NDT infrastructure to produce certified personnel	Average personnel certified in conventional and advanced techniques under the RCA NDT programme per year for the period 2000 to 2020	2 807
Self-reliance in NDT	Inspection centres owned by local firms	3 607
Self-reliance in NDT	Training centres owned by local firms	191

Table 1: Key evidence for criterion 1: Improved NDT capacity and capability

Moreover, Figure 6 below shows each State Party's level of performance in developing their capacity and capability for each NDT dimension.

The detailed analysis of each sub-criterion under improved NDT capacity and capability is presented in the sections below.

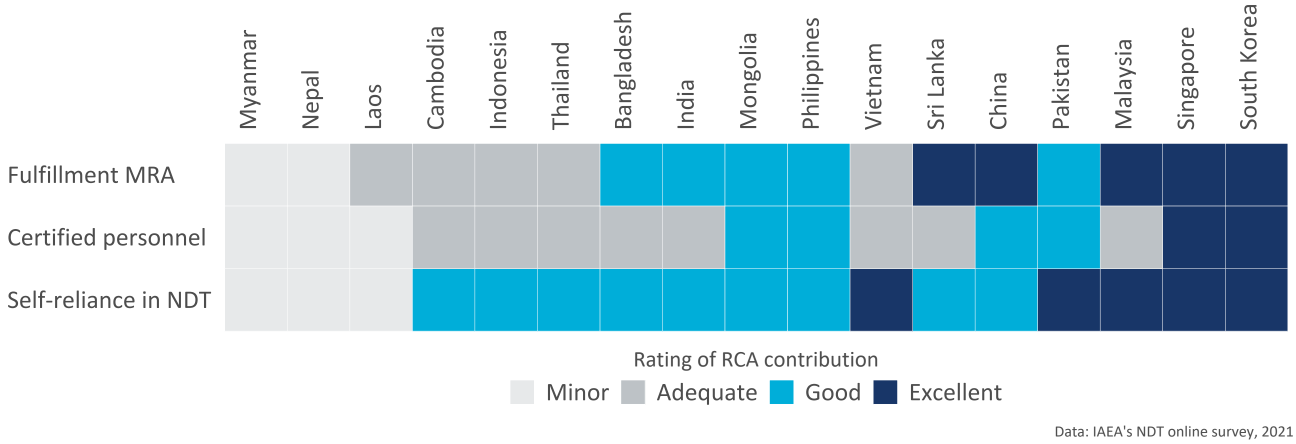


Figure 6: Capacity and capability: Rating of RCA contributions

14 Conventional methods include Radiographic Testing (RT), Ultrasonic Testing (UT), Magnetic Testing (MT), Penetrant Testing (PT), Eddy Current Testing (ET), and Visual Testing (VT). Advanced techniques include Radiographic Testing – Digital (RT-D), Phased Array Ultrasonic Testing (PAUT), Time of Flight Diffraction (TOFD) and Pulsed Eddy Current (PEC).

Sub-criterion 1.1: Fulfilment of the Multilateral Recognition Agreement

This criterion aims to understand the extent to which a State Party has fulfilled the MRA requirements of ICNDT and the status of the NDT infrastructure at the national level. The standards (levels of performance) for the Fulfilment of the Multilateral Recognition Agreement are the following:

- **Excellent:** State Party's NDT Society is registered with APFNDT and ICNDT, the society is a signatory to ICNDT MRA, NCB for NDT has been accredited to ISO 17024, and NCB has accepted for registration under the ICNDT MRA.
- **Good:** State Parties have established a NCS and a National Certification Body (NCB) on NDT.
- **Adequate:** State Parties have established a National Certification Scheme (NCS).

Performance standards of 'Fulfilment of the Multilateral Recognition Agreement'

From the 18 countries that act as recipients of RCA, only Nepal and Myanmar have not established a National Certification Scheme yet. Almost all countries but Laos, Cambodia, Nepal and Myanmar have registered their NDT society in the Asia Pacific Federation for NDT (APFNDT); and 8 out of the 18 recipient State Parties, their NCB for NDT has been accredited to ISO 17024. Figure 7 shows the level of NDT infrastructure that each recipient State Party has established and the performance for this criterion.

Based on the criterion developed with IAEA to assess the performance of State Parties in terms of Fulfilment of the Multilateral Recognition Agreement, China, Malaysia, Singapore and South Korea met excellent performance standards on this criterion.

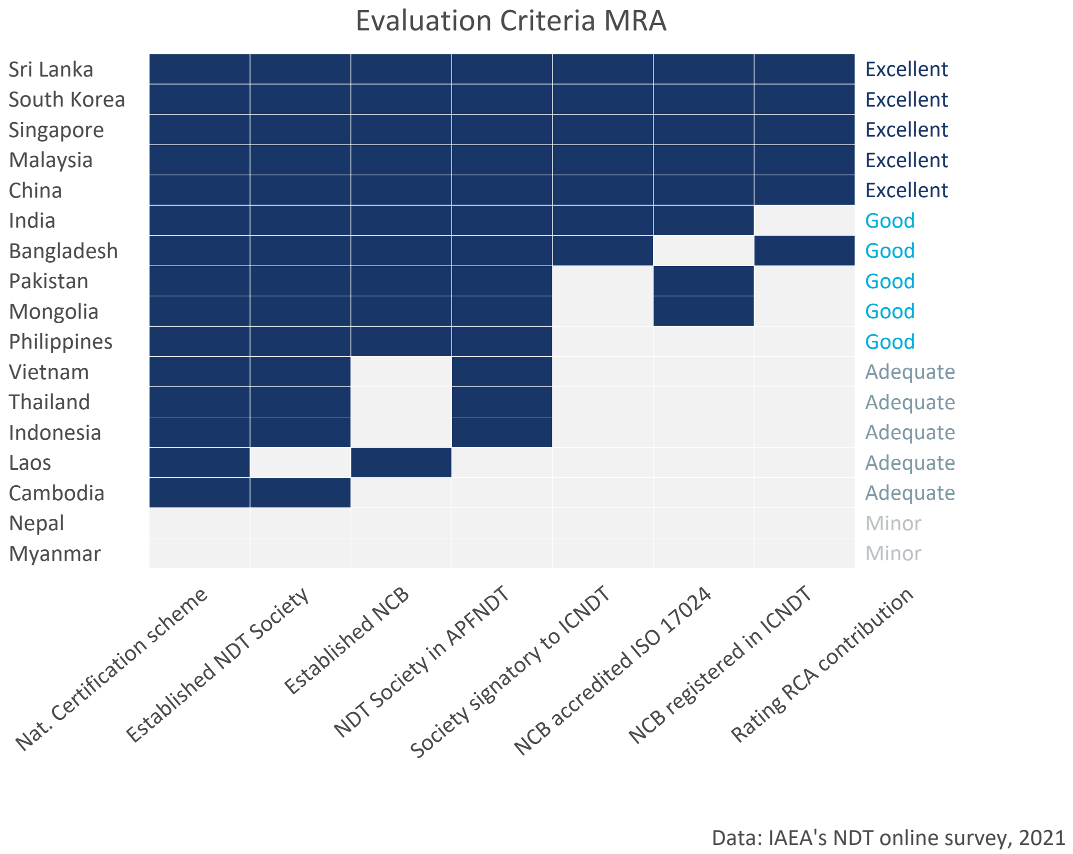


Figure 7: NDT infrastructure at the national level – standards for fulfilment of MRA

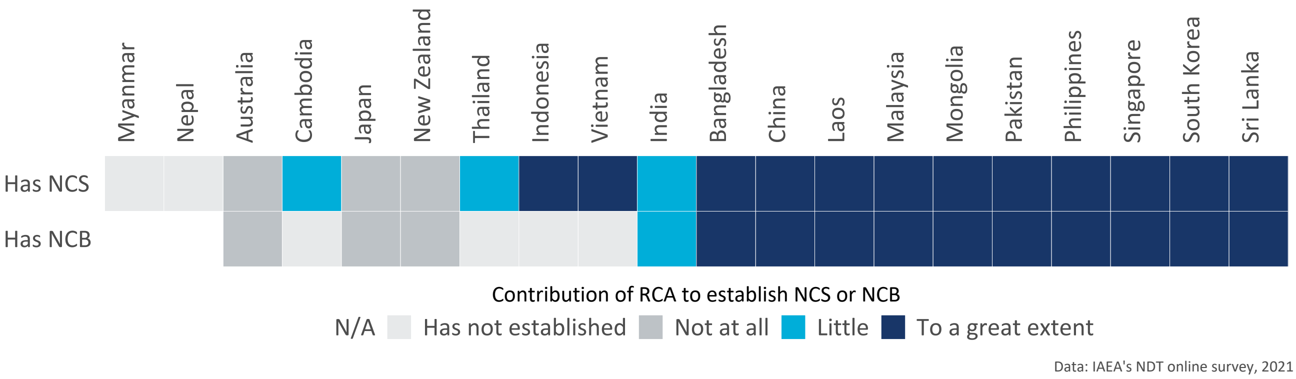


Figure 8: Contribution of the RCA to NDT infrastructure

Contribution of the RCA NDT programme in State Parties establishing a NCB and NCS

To assess the contribution of RCA in the establishment of a National Certification Body (NCB) and National Certification Schemes (NCS), the participants of the online survey were asked the extent to which they perceive that the RCA NDT programme has contributed to the establishment of this infrastructure in their countries.

As can be seen in the Figure 8, from the 11 State Parties that have established a NCB under RCA, ten (Bangladesh, China, Laos, Malaysia, Mongolia, Pakistan, Philippines, Singapore, South Korea and Sri Lanka) perceived that the RCA has contributed to a great extent in the establishment of their body. As it was expected (because of their historical role as non-recipient countries), only Australia, Japan and New Zealand perceive that the establishment of their NCB could have been achieved without the support of the RCA.

Moreover 58 per cent of the State Parties that are recipients of the programme perceive that the RCA has contributed to a great extent in the establishment of the certification scheme of their countries.

Sub-criterion 1.2: NDT infrastructure to produce certified personnel

This section presents the findings on the extent to which the RCA NDT programme has supported State Parties in establishing NDT infrastructure through the RCA, and has enabled State Parties to produce certified personnel in conventional methods (RT, UT, MT, PT, ET) and in advanced techniques (RT-D, PAUT, TOFD, PEC, etc). The standards for this dimension are the following:

- **Excellent:** The support in establishing State Parties' NDT infrastructure through the RCA has enabled State Parties to produce certified personnel in all levels of NDTs' five main methods (RT, UT, MT, PT, ET) through the national NDT certification scheme.
- **Good:** The support in establishing State Parties' NDT infrastructure through the RCA has enabled State Parties to produce certified personnel in all levels of NDTs' five main methods (RT, UT, MT, PT, ET) through the national NDT certification scheme.
- **Adequate:** There are certified personnel produced by the national NDT certification scheme, however, for limited method(s) and not for all five main methods.

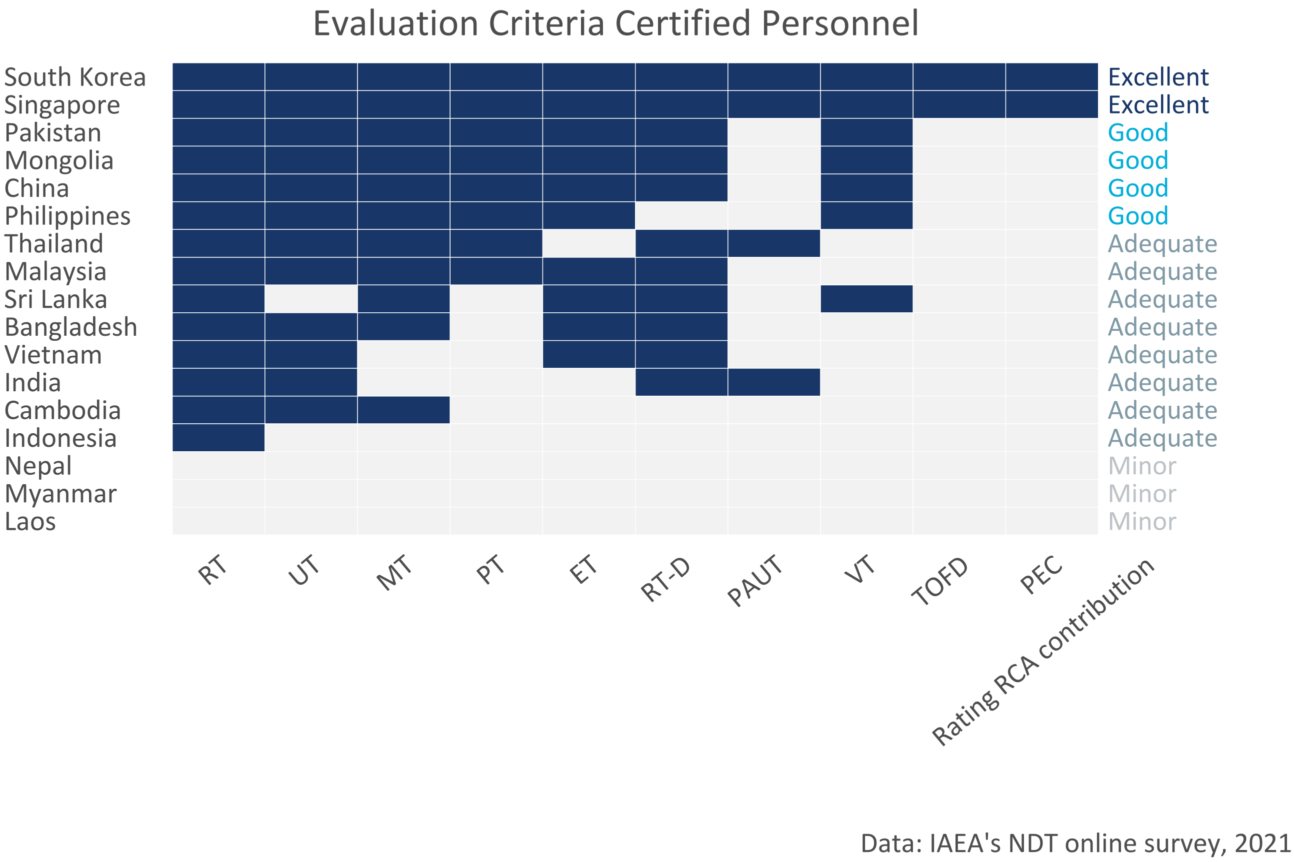


Figure 9: Personnel certified by methods – standards for self-reliance

Performance standards of 'NDT infrastructure to produce certified personnel'

Figure 9 shows that based on the criterion developed with IAEA, two countries have met an excellent standard (Singapore and South Korea) because the RCA NDT programme has contributed or facilitated the introduction of all methods and techniques to their personnel. Four State Parties met a good standard (China, Mongolia, Pakistan and Philippines) because the RCA NDT programme has facilitated the certification of their personnel in all the conventional techniques.

In Laos, Myanmar and Nepal, the RCA was not considered to make a significant contribution to the certification of their personnel in any of these techniques.

Contribution of the RCA NDT programme in the certification of personnel

As can be seen in Table 2, From 2000 to 2020, the RCA NDT Programme has contributed yearly to the certification of roughly 2 807 personnel by local NDT Accredited Training Centres in 15 countries (Bangladesh, Cambodia, China, India, Indonesia, Japan, Malaysia, Mongolia, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Thailand and Vietnam). From the total certified personnel, 10.3 per cent are female.

The method for which the RCA has contributed the most to the certification of personnel is Radiographic Testing (15 180 personnel trained), followed by Magnetic Testing and Penetrant Testing.

As can be seen in the table below, it is possible that RCA NDT programme has indeed sensitised and provided awareness in State Parties for the introduction of certification in the main and advanced NDT techniques. For some countries, “RCA had helped introduce and sensitise the NDT programme in the early years of cooperation. However, in the last 20 years, NDT centres in the country did conduct training and certification programmes under the national NDT Society and others but they have not been, necessarily, in association with RCA” (National expert, online survey 2021).

Method	Accronym	Type of technique	Average number of personnel certified per year under RCA	Approximate number of personnel certified from 2000 to 2020 under RCA	(%) of Certified female personnel	Countries supported by RCA NDT
Radiographic Testing	RT	Conventional	759	15 180	5.15%	15
Magnetic Testing	MT	Conventional	594	11 880	13.18%	12
Penetrant Testing	PT	Conventional	550	11 000	12.59%	9
Ultrasonic Testing	UT	Conventional	533	10 660	10.1%	13
Eddy Current Testing	ET	Conventional	187	3 740	7.03%	11
Visual Testing	VT	Conventional	119	2 380	7.16%	7
Radiographic Testing - Digital	RT-D	Advanced technique	37	740	14.54%	10
Phased Array Ultrasonic Testing	PAUT	Advanced technique	14	280	20%	5
Time of Flight Diffraction	TOFD	Advanced technique	7	140	20%	2
Pulsed Eddy Current	PEC	Advanced technique	7	140	20%	2
Total	–	–	2 807	56 140	10.26%	15

Table 2: Number of certified personnel by country and technique

The total number of certified personnel under the RCA by country, technique and sex is presented in Figure 10 below.

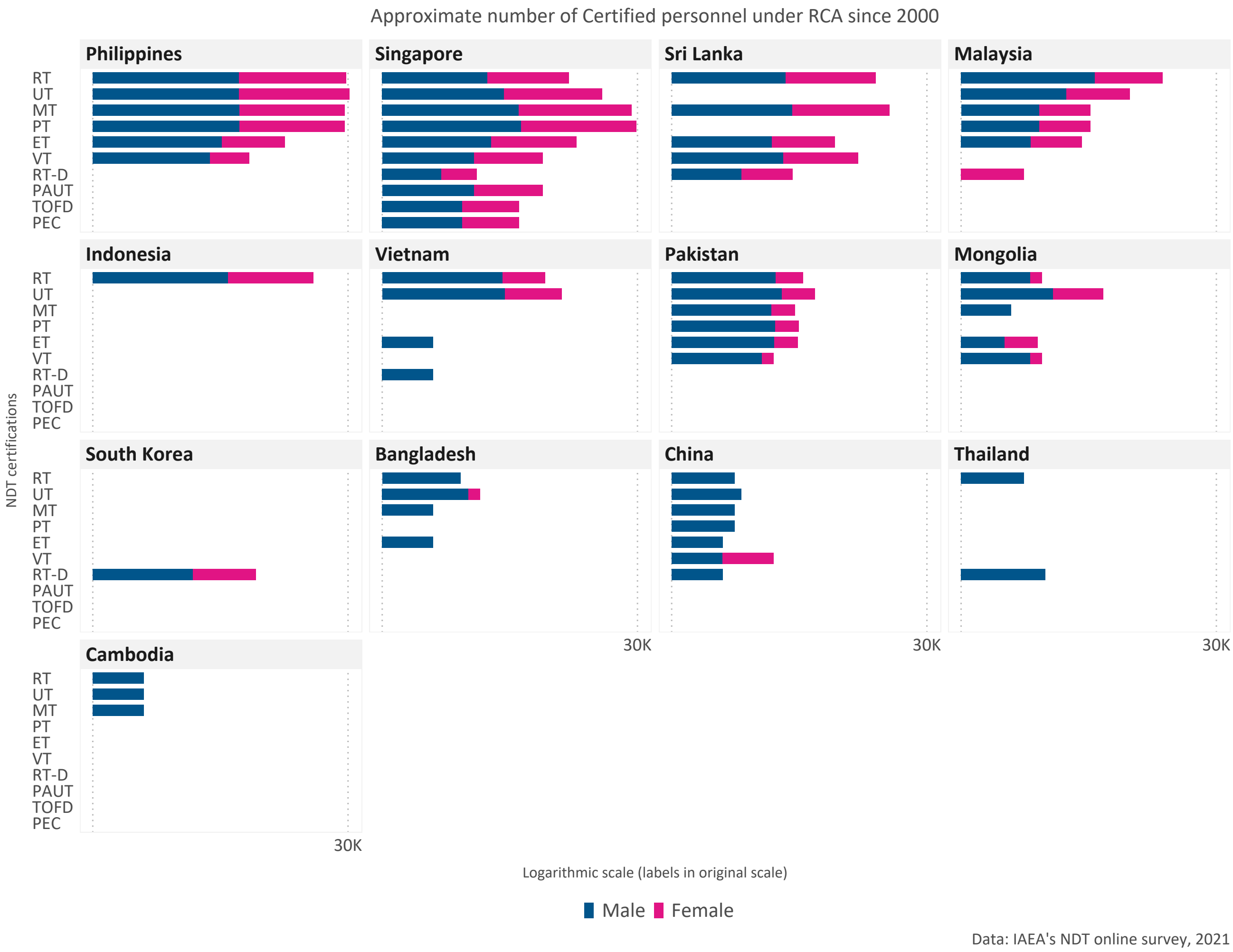


Figure 10: Number of personnel certified by local NDT training centres as a result of participating in the RCA NDT programme

Sub-criterion 1.3: Self-reliance in NDT

Self-reliance in NDT is a function of countries having the capacity to conduct inspection and train personnel without depending on external stakeholders. An assessment to map whether State Parties have inspection and training centres owned locally or by foreigners was conducted to estimate the level of self-reliance that each State Party has. According to the criterion developed, a State Party is considered to have an excellent standard (or to have achieved increased self-reliance) if their local inspection and training centres offer their services abroad. On the other hand, the impact of a State Party's self-reliance is considered minor if it does not have both training and certification centres owned either by local or foreign firms.

The levels of performance for this criterion are the following:

- **Excellent:** State Parties have achieved increased self-reliance in NDT, including offering training and inspection activities to local industries as well as abroad.
- **Good:** State Parties have local NDT training centres and inspection companies offering services to local industry.
- **Adequate:** State Parties have training centres and inspection companies, owned by foreign entities.

Performance standards of 'Self-reliance in NDT'

As it can be seen in Figure 11, out of the 18 recipient countries, 5 (Malaysia, Pakistan, Singapore, South Korea and Vietnam) offer both training and inspection abroad. Moreover, Myanmar and Nepal do have access to inspection centres (either owned locally or by foreigners) but they do not have training centres offering services in their countries.

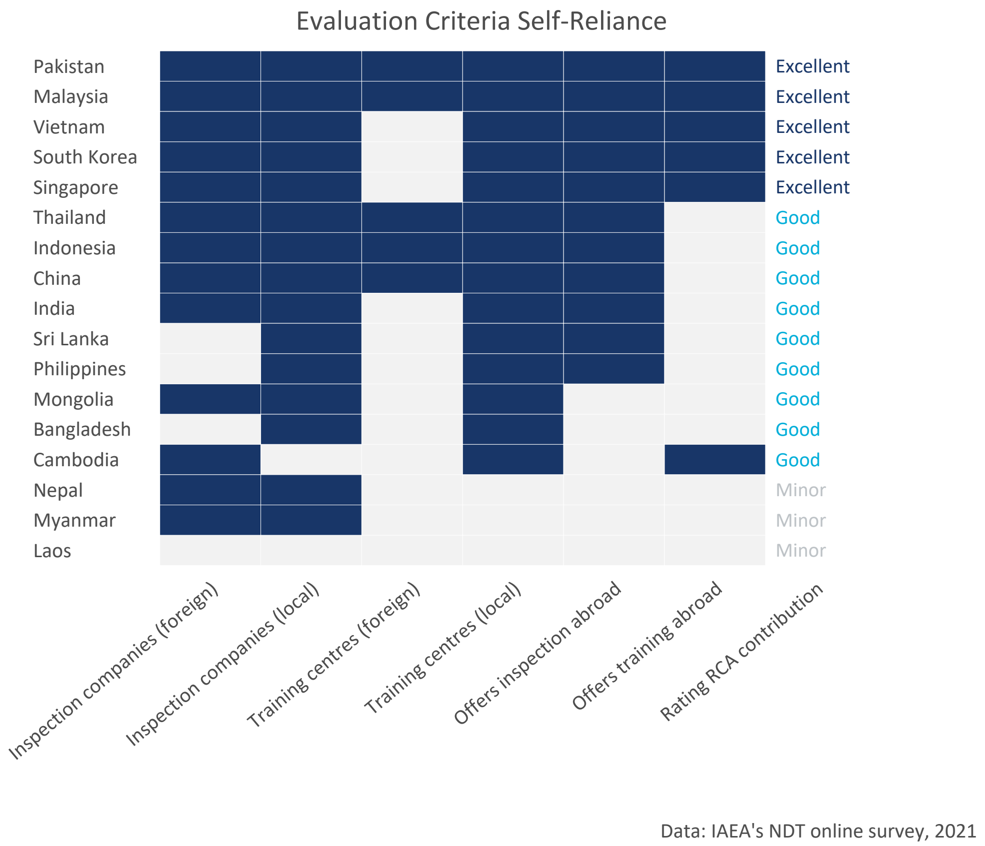


Figure 11: Inspection and training centres – standards for self-reliance

Contribution of RCA in the development of local inspection and training centres

According to the perception of respondents from the State Parties, the RCA NDT programme has contributed to a great extent in the establishment of inspection centres in nine of the twenty-two countries that are part of the programme (Bangladesh, China, Indonesia, Malaysia, Pakistan, Philippines, Singapore, South Korea and Vietnam). In ten countries, the RCA has facilitated the investment in local inspection centres, and twelve countries perceived that RCA has contributed to a great extent in the establishment of local training centres (See Figure 12).

An interesting finding is that although New Zealand has been an historical non-recipient country, their perception is that RCA has contributed to a great extent in the establishment of local training centres in their country.

"Although NZE received no direct assistance, the IP & knowledge/contacts…gained by being involved in the RCA NDT projects, has guided/aided the establishment of a new NDT Training Model established this year (NZNDTA)".

The white asterisk in the figure below indicates that RCA has facilitated the investment in local inspection centres in those countries.

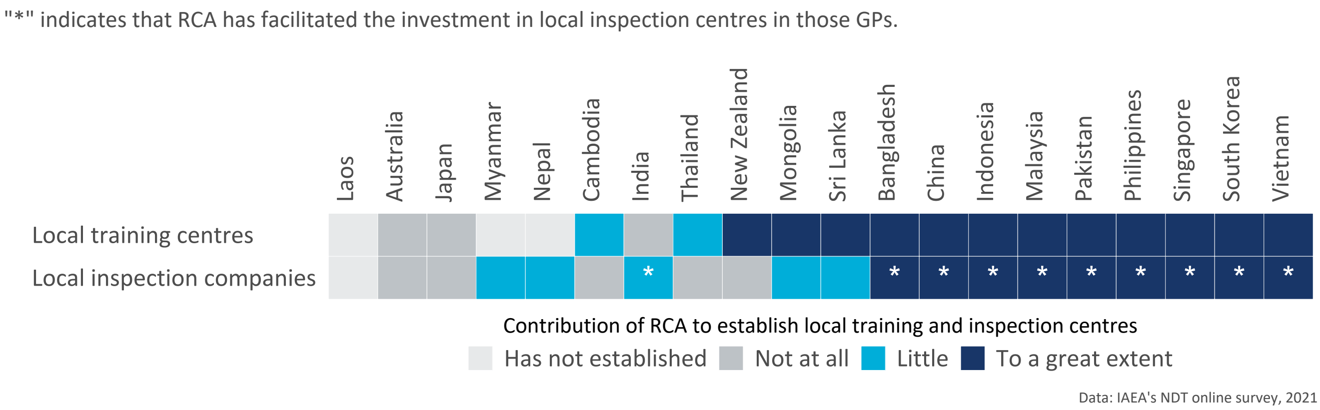


Figure 12: The contribution of the RCA NDT programme to the establishment of local inspection and training centres

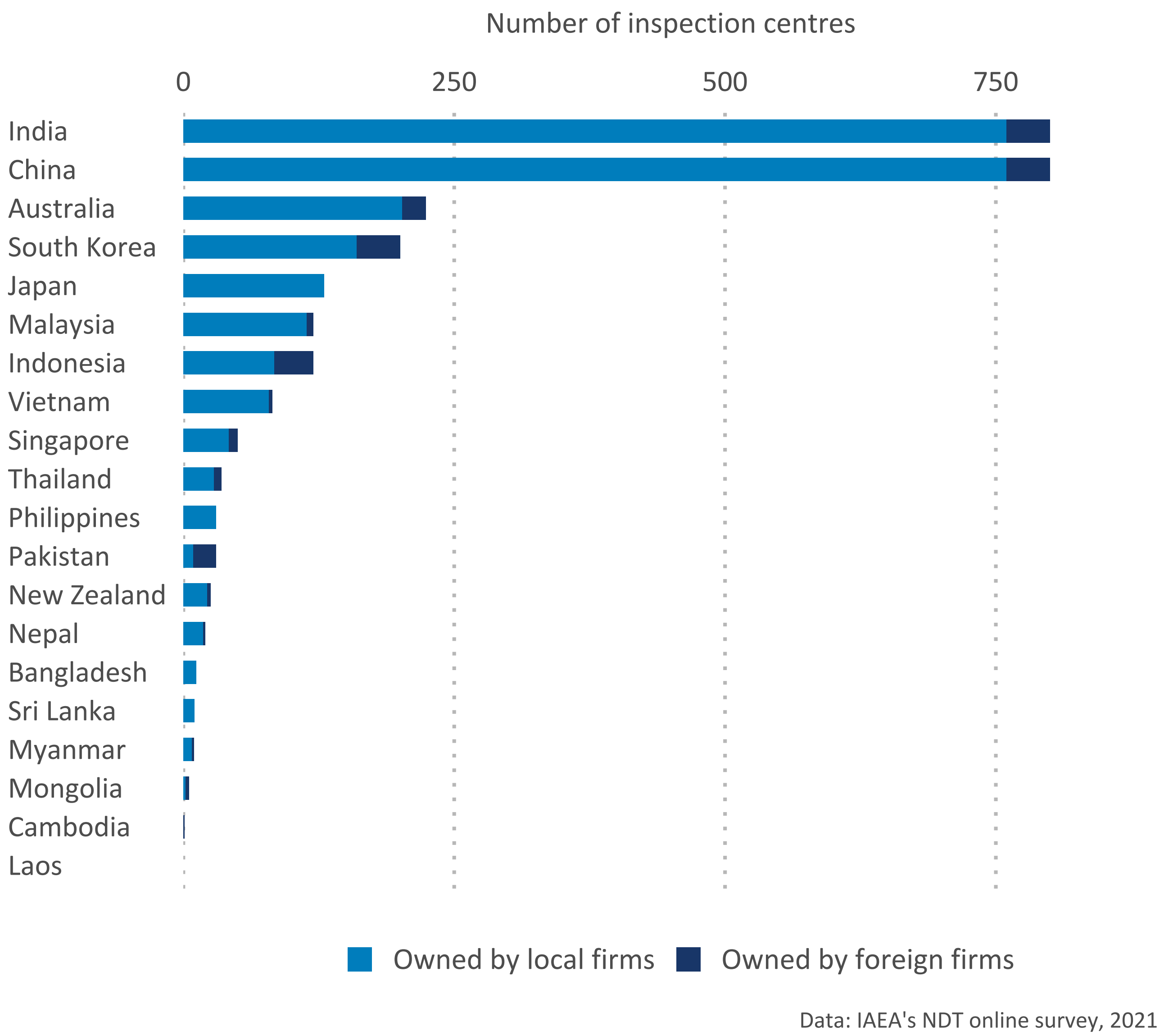


Figure 13: Number of inspection centres by type of ownership and country

Figure 13 shows the number of inspection centres owned by local and foreign firms in each RCA country. As it can be observed in the figure, there are over 3 607 inspection centres owned by local firms across all the State Parties that participate in the RCA NDT programme, of which about half are located on only two RCA countries.

Figure 14 shows the number of training centres owned by local and foreign firms in each RCA country. Across all the State Parties that are part of the RCA NDT programme, there are a total of 191 training centres owned by local firms, of which more than half are in India and China.

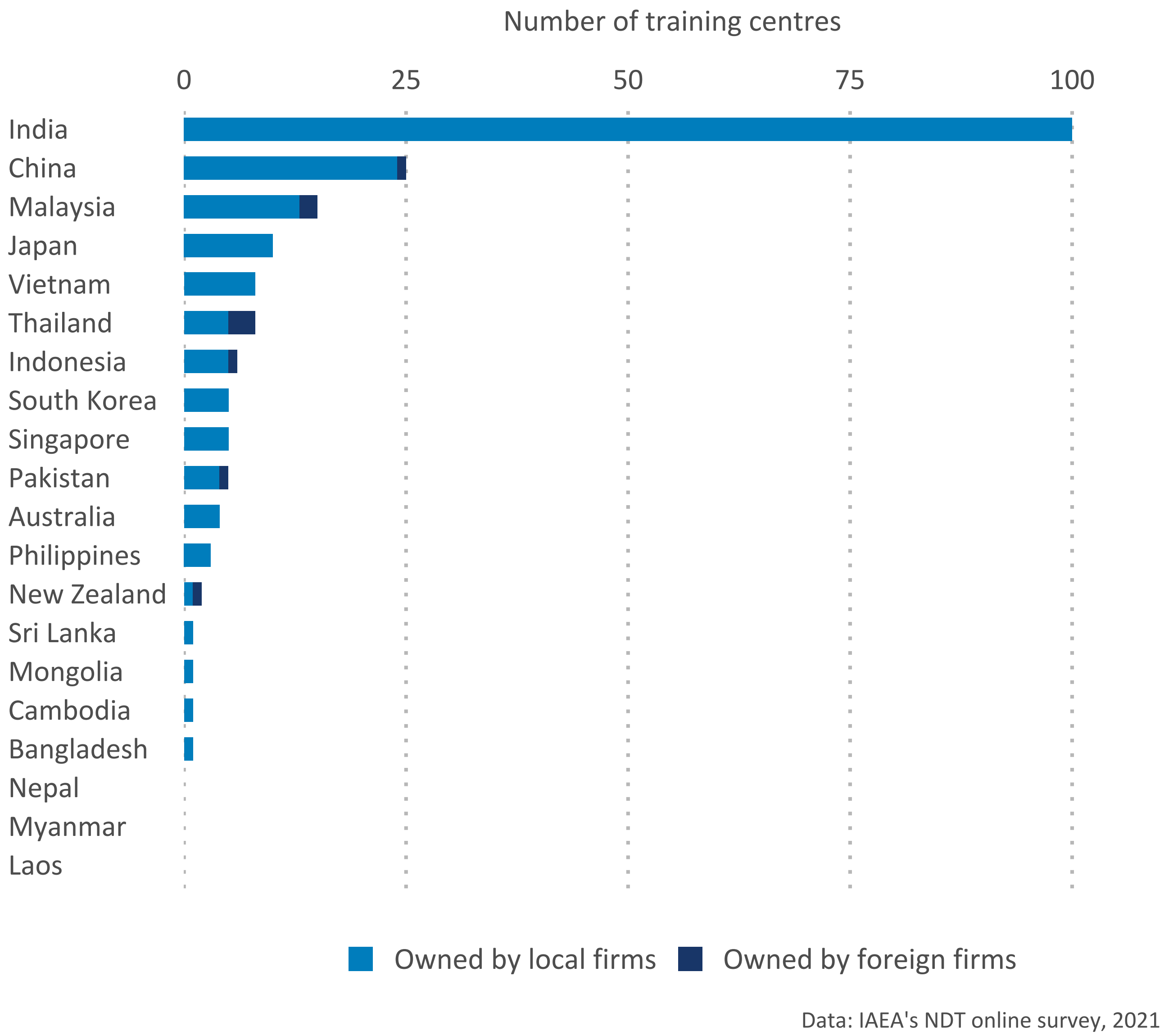


Figure 14: Number of training centres by type of ownership and country

Criterion 2: Increased scope and scale of NDT demand and use

This section presents findings on the contribution of the RCA NDT programme to the increased scope and scale of NDT demand and use in the countries surveyed. Particularly, the analysis aims to understand the extent to which the support of the NDT programme has contributed to the enhancement of:

- Awareness, interest, and application of NDT technology in the industrial sectors for the QA and QC of industrial components; and
- Knowledge developed through R&D by publishing research articles, organising international and national seminars and conferences.

Sub-criterion	Evidence	Finding
Awareness, interest, and application of NDT technology	Per cent of recipient State Parties that have taken actions to create awareness among industrial organisations about the benefits of NDT technology for Quality Assurance and Quality Control	90%
Awareness, interest, and application of NDT technology	Per cent of recipient State Parties that have applied NDT technology for Quality Assurance and Quality Control in at least one industrial sector	95%
Knowledge developed through R&D	Per cent of State Parties that have established any R&D activities related to NDT	75%
Knowledge developed through R&D	Number of publications related to NDT that have been published since 2000 in as a result of being part of the RCA NDT programme	1 620

Table 3: Key evidence for criterion 2: Increased scope and scale of NDT demand and use

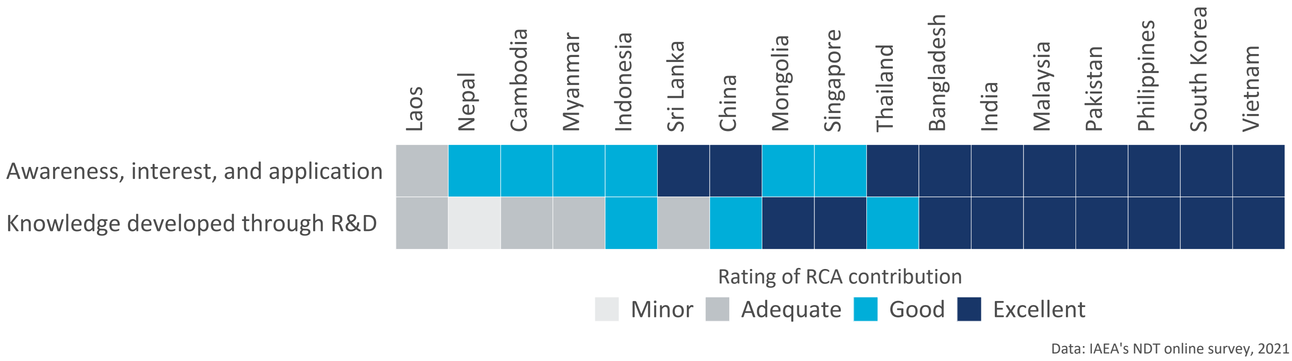


Figure 15: Increased scope and scale of NDT demand and use – rating of RCA contribution

Moreover, Figure 15 shows the performance standards of the impact of the RCA NDT programme on the increased scope and scale of NDT demand and use of the recipient State Parties.Figure 15: Increased scope and scale of NDT demand and use – rating of RCA contribution

The detailed analysis of each sub-criterion under improved NDT capacity and capability is presented in the sections below.

Sub-criterion 2.1: Awareness, interest and application

This sub-criterion explores the extent into which participation in the RCA results in State Parties applying NDT technology in the industrial sectors for the QA and QC of industrial components, achieving better controlled manufacturing, lower production costs, ensuring material quality and/or greater product integrity.

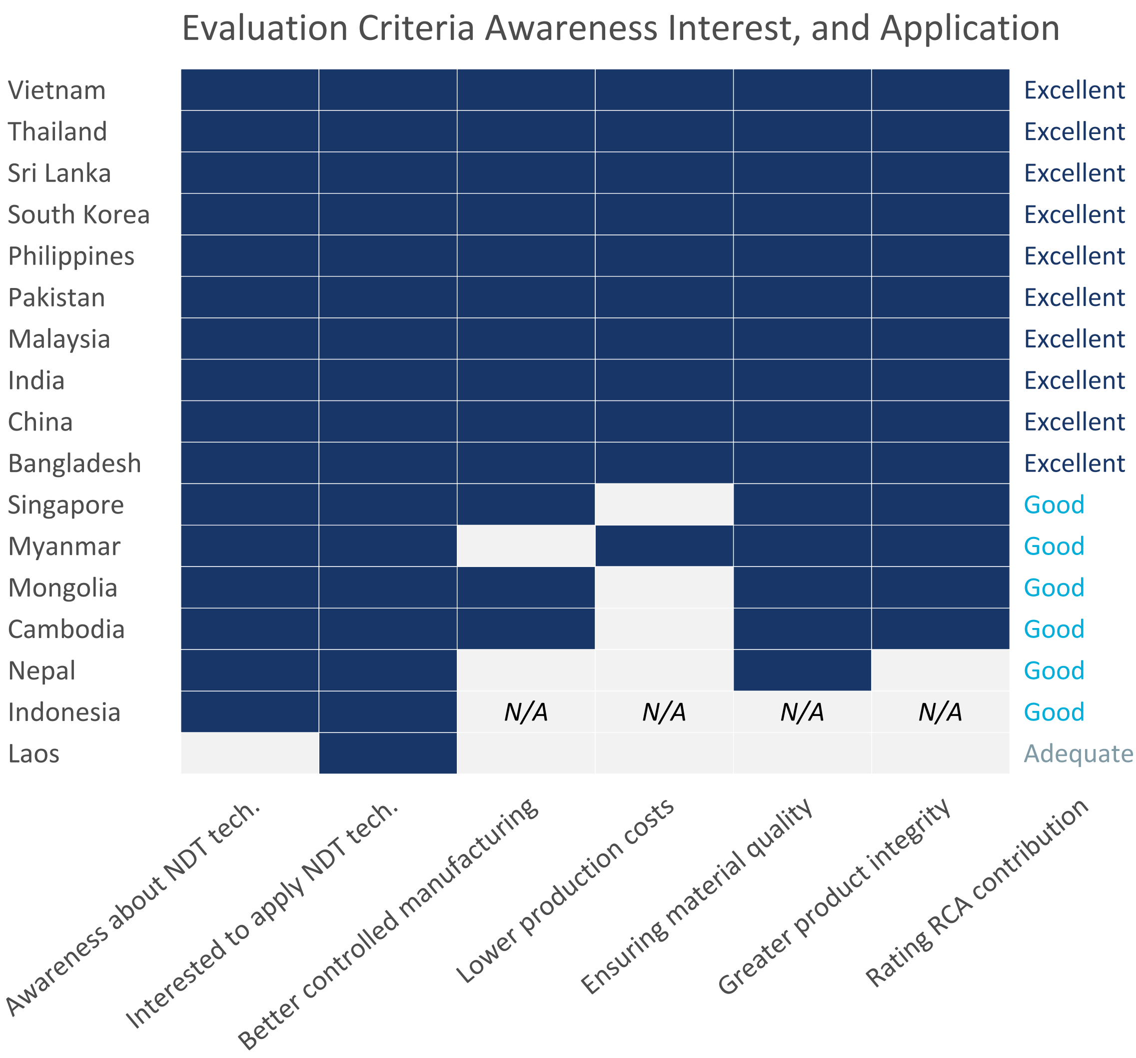
- **Excellent:** Participating in the RCA results in State Parties applying NDT technology in at least one industrial sector for the QA and QC of industrial components – achieving better controlled manufacturing, lower production costs, ensuring material quality and/or greater product integrity.
- **Good:** as a result of being part of the RCA NDT programme, State Parties become more concerned and interested in applying NDT technology in the industrial sectors.
- **Adequate:** the RCA NDT programme has contributed to State Parties initiating activities to create awareness among industrial organisations about the benefits of NDT technology for QA and QC.

Performance standards of 'Awareness, interest and application of NDT technologies'

Bangladesh, China, India, Malaysia, Pakistan, Philippines, South Korea, Sri Lanka, Thailand and Vietnam are considered to have met an excellent performance standard in this sub-criterion, because as a result of applying NDT technology, positive improvements have been achieved in terms of *controlled manufacturing, lower production costs, ensuring material quality and greater productivity for at least one industrial sector* (all the positive improvements by country and industrial sector is presented in the next section).

Moreover, the ten recipient State Parties that met an excellent standard have taken actions to create awareness among industrial organisations about the benefits of NDT technology. For all these State Parties, being part of the RCA NDT programme has also contributed to increasing the level of concern and interest in applying NDT technologies for Quality Assurance and Quality Control in their industrial sectors.

Figure 16 shows the criteria and standards for this sub-dimension. The N/A in the chart indicates that this information was not provided by those State Parties during the online survey.



The "N/A" indicates that information was not provided during the online survey.
Data: IAEA's NDT online survey, 2021

Figure 16: Awareness, interest, and application of NDT technology in the industrial sectors for QA and QC of industrial components – standards for application

Contribution of the RCA NDT programme to awareness, interest and application of NDT technologies

Table 4 shows that ten of the State Parties have taken action to create awareness among industrial organisations about the benefits of NDT technology for Quality Assurance and Quality Control. The table also shows the actions taken by these State Parties.

Country	Has taken actions to create awarenes about benefits of NDT	Has conducted seminars, workshops and/ or forums	Has engaged with policymakers and regulatory body(s)	Has conducted talks in universities or colleges
Australia	Yes	Yes	Yes	No
Bangladesh	Yes	Yes	Yes	Yes
Cambodia	Yes	Yes	Yes	No
China	Yes	Yes	Yes	Yes
India	Yes	Yes	Yes	Yes
Indonesia	Yes	Yes	Yes	Yes
Japan	No			
Laos	No			
Malaysia	Yes	Yes	Yes	Yes
Mongolia	Yes	No	Yes	No
Myanmar	Yes	Yes	Yes	Yes
Nepal	Yes			
New Zealand	Yes	Yes	Yes	Yes
Pakistan	Yes	Yes	Yes	Yes
Philippines	Yes	Yes	Yes	Yes
Singapore	Yes	Yes	Yes	Yes
South Korea	Yes	Yes	Yes	Yes
Sri Lanka	Yes	Yes	No	Yes
Thailand	Yes	Yes	Yes	Yes
Vietnam	Yes	Yes	Yes	Yes

Table 4: Actions taken by State Parties to create awareness among industrial organisations about the benefits of NDT technology for Quality Assurance and Quality Control

The number of industrial sectors in which NDT technology has been applied for quality control and quality assurance in each State Party is presented in Figure 17 below. The maximum total of sectors asked were 11: oil and gas, power generation (excluding nuclear), petrochemical, chemical, aerospace, manufacturing, railway, nuclear, construction, shipping and other.

The extent to which the introduced NDT technology by the RCA led to improved manufacturing processes, lower production costs, enhanced material quality and greater product integrity in each industrial sector is presented in a supplementary table at the end of this Annex. *For some countries, the information is missing because they did not provide this information in the online survey.*

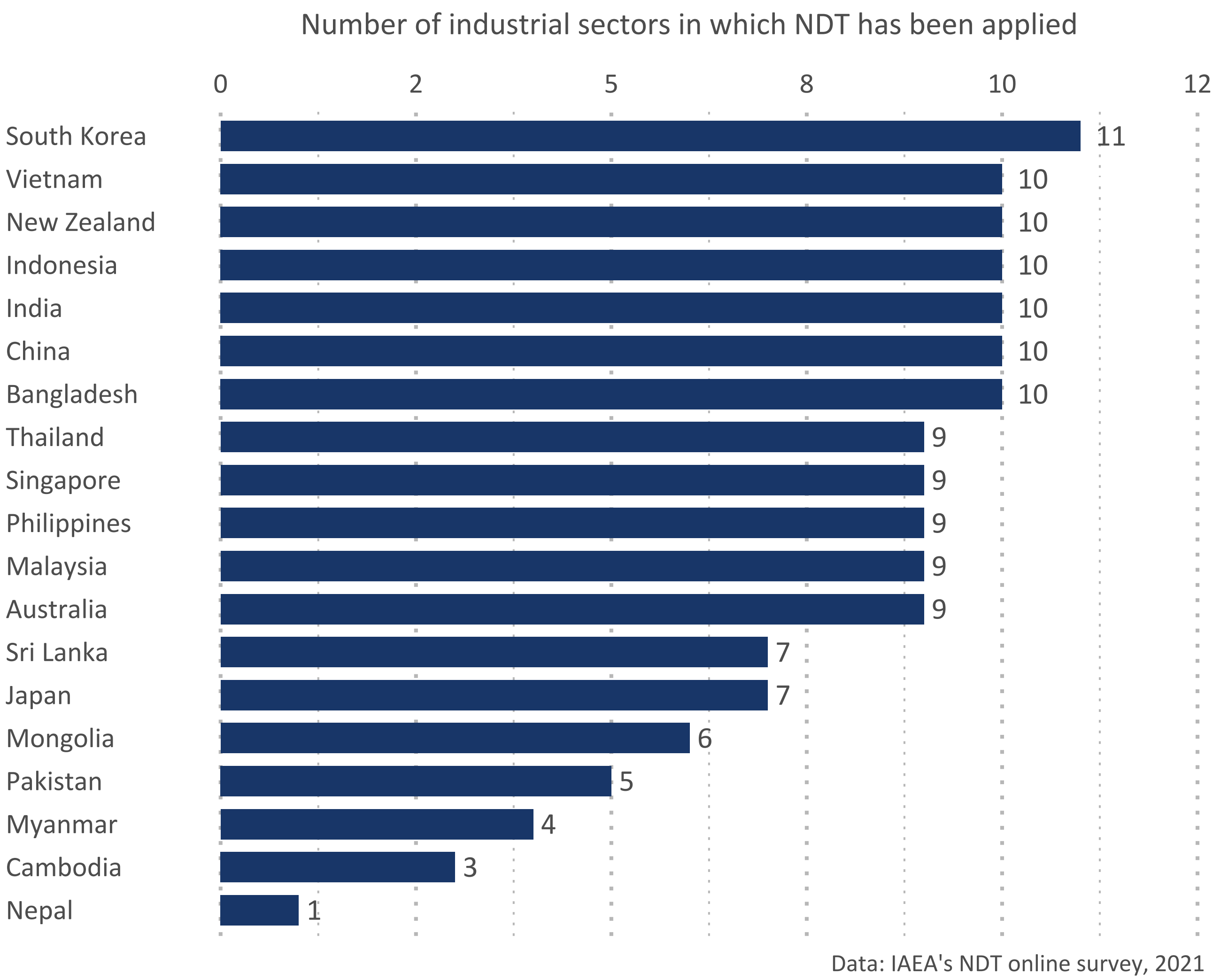


Figure 17: Number of industrial sectors in which NDT technology has been applied by State Parties

Sub-criterion 2.2: Research and Development

This section aims to understand the extent into which the RCA NDT programme has contributed to the dissemination of knowledge developed through R&D.

The standards for this criterion are the following:

- **Excellent:** As a result of participating in the RCA NDT programme, State Parties have managed to support the utilisation of the technology by industry and disseminate the knowledge developed through R&D by publishing research articles, organising international and national seminars and conferences.
- **Good:** The RCA NDT programme has enabled State Parties to have successfully applied the NDT technology to local industry, and established R&D activities.
- **Adequate:** State Parties have successfully managed to train personnel in the introduced NDT technology.

Performance standards of 'Research and Development'

From the 18 recipient State Parties that participated in the study, nine State Parties (Bangladesh, India, Malaysia, Mongolia, Pakistan, Philippines, Singapore, South Korea and Vietnam) met an excellent performance in R&D, because as a result of participating in the RCA NDT programme they have published research articles and have organized international and national seminars and conferences.

Because China, Indonesia, and Thailand have established R&D activities but have not published or organized seminar under RCA, their performance meets the defined standard for good performance in terms of R&D. Figure 18 shows the State Parties' performance in terms of R&D.

Contribution of the RCA NDT programme in Research and Development

Figure 19 shows the extent to which the RCA NDT programme enabled or promoted the initiation of R&D activities related to NDT. As can be seen in the chart, RCA has contributed to a great extent to enable or promote the initiation of R&D in eight countries. It is worth mentioning that although Japan has historically been a non-recipient country, they reported that RCA has contributed to a great extent in the promotion and initiation of R&D activities in their country.

A total of 2 674 personnel have been trained in NDT under the RCA NDT programme. Figure 20 shows the number of personnel who have been trained in NDT under the RCA NDT programme by country.

As can be seen in Figure 21, since 2000 a total of 1 620 publications related to NDT have been published as a result of State Parties being a part of the RCA NDT programme.

According to respondents 4 300 seminars/conferences related to NDT have been organised since 2000 as a result of State Parties being a part of the RCA NDT programme (Figure 22).

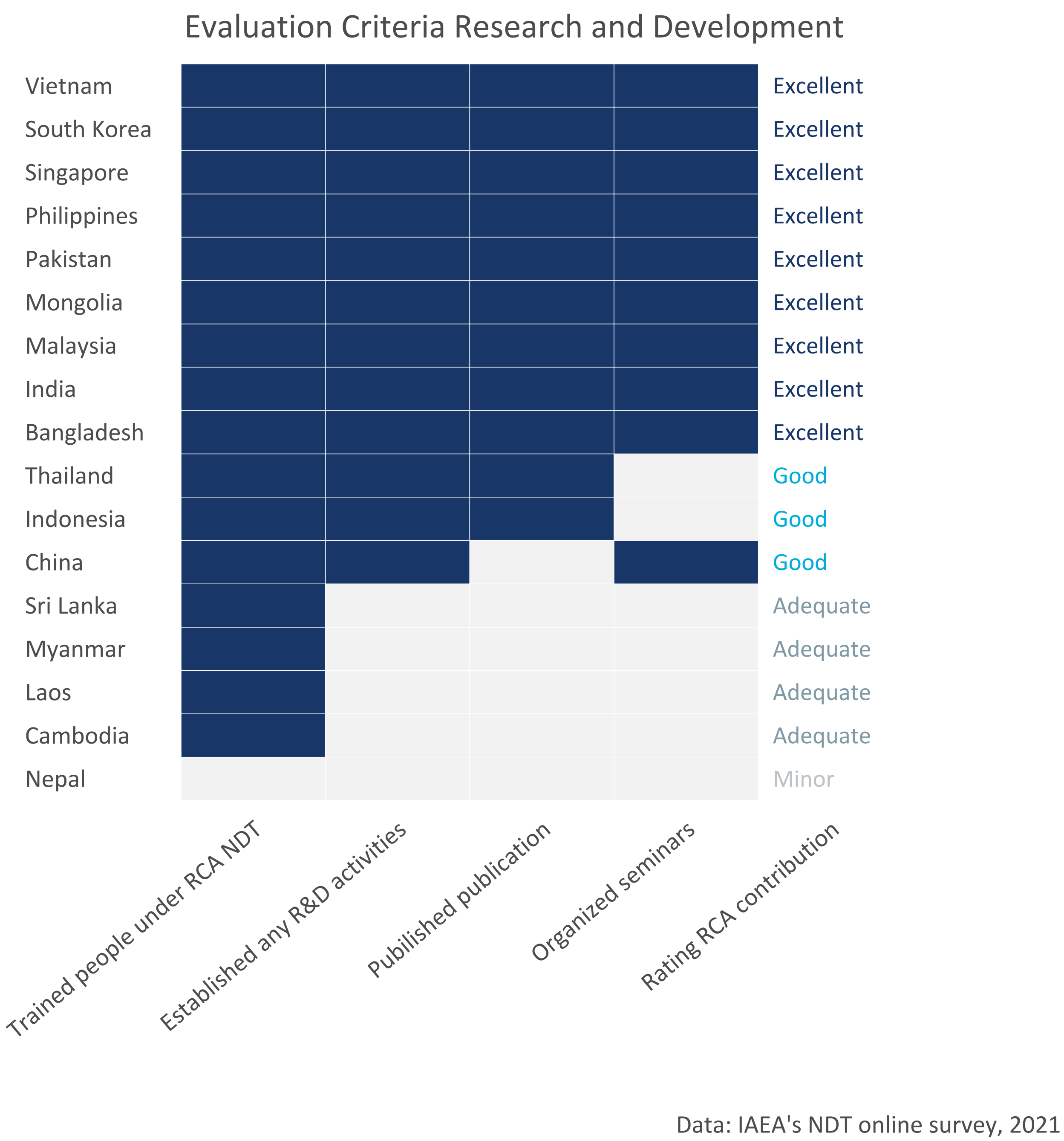


Figure 18: Rearch and development – performance against standards

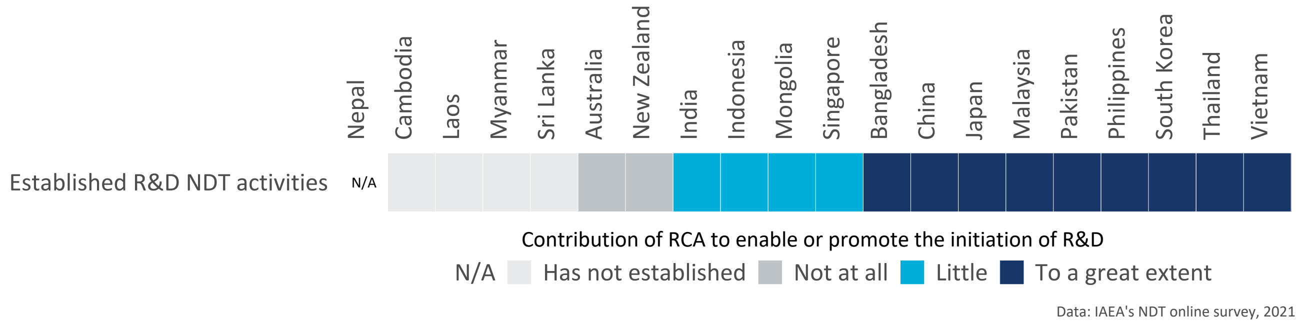


Figure 19: Extent to which RCA NDT programme enabled or promoted the initiation of R&D activities related to NDT

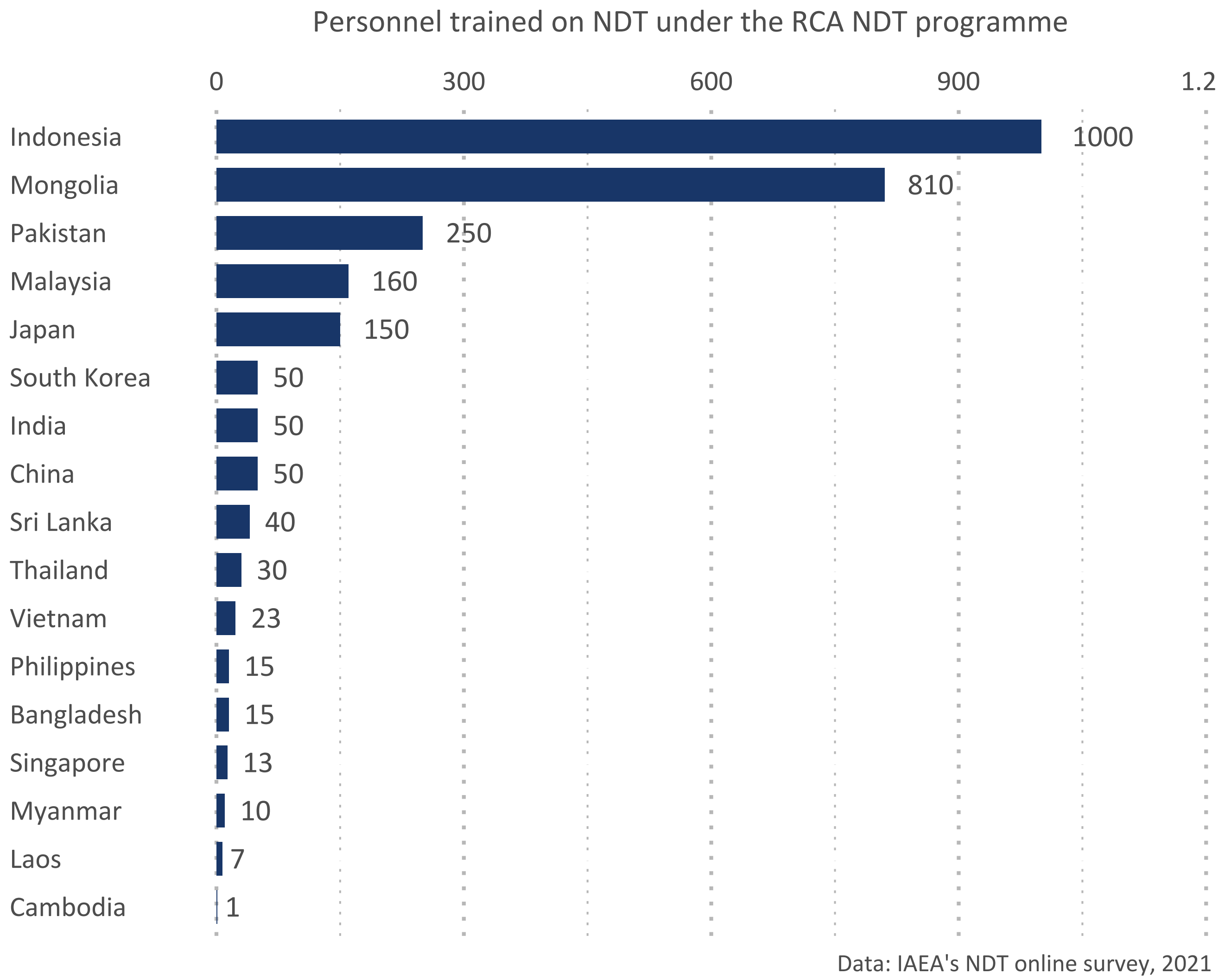


Figure 20: Personnel trained in NDT under the RCA NDT programme

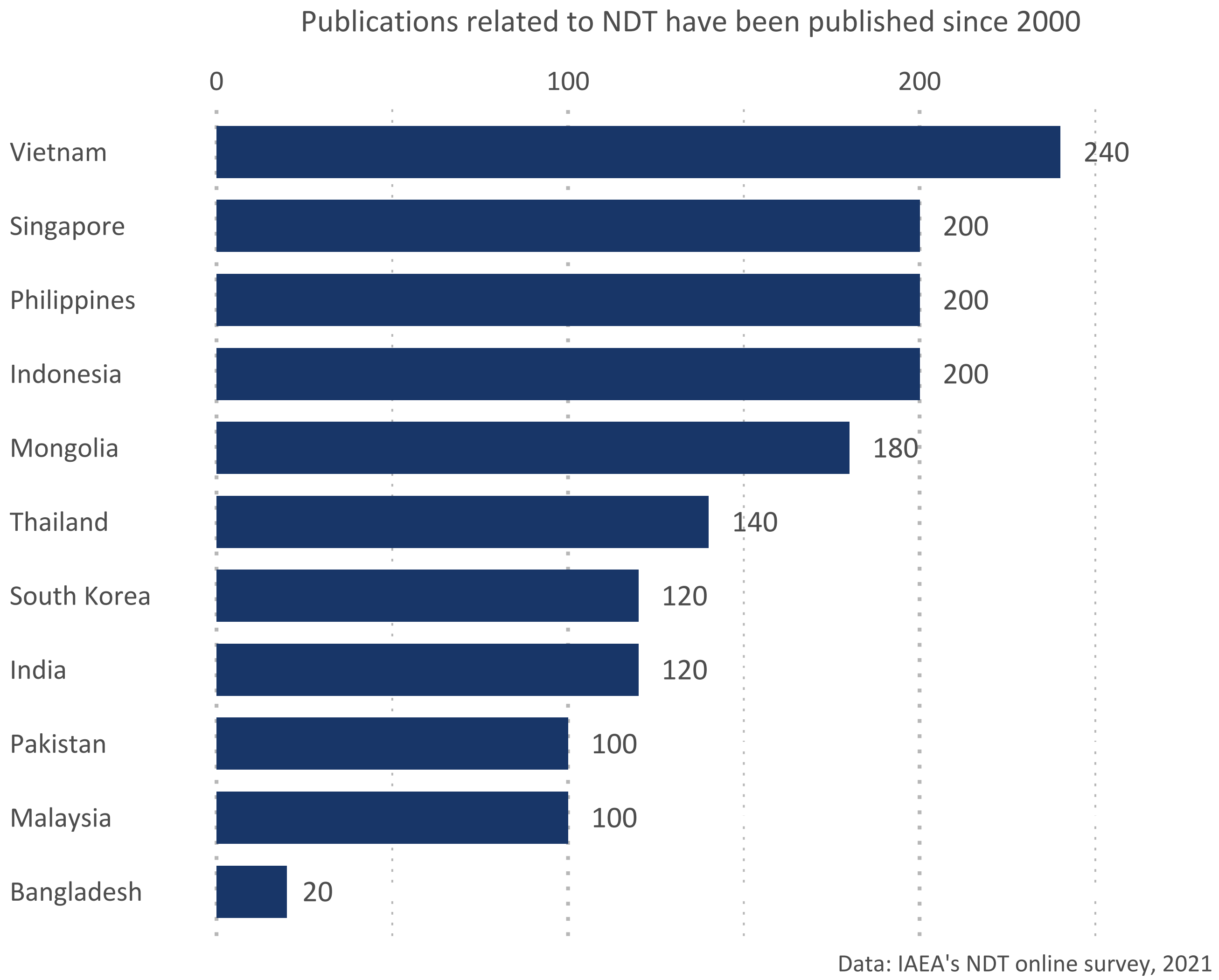


Figure 21: Publications related to NDT since 2000

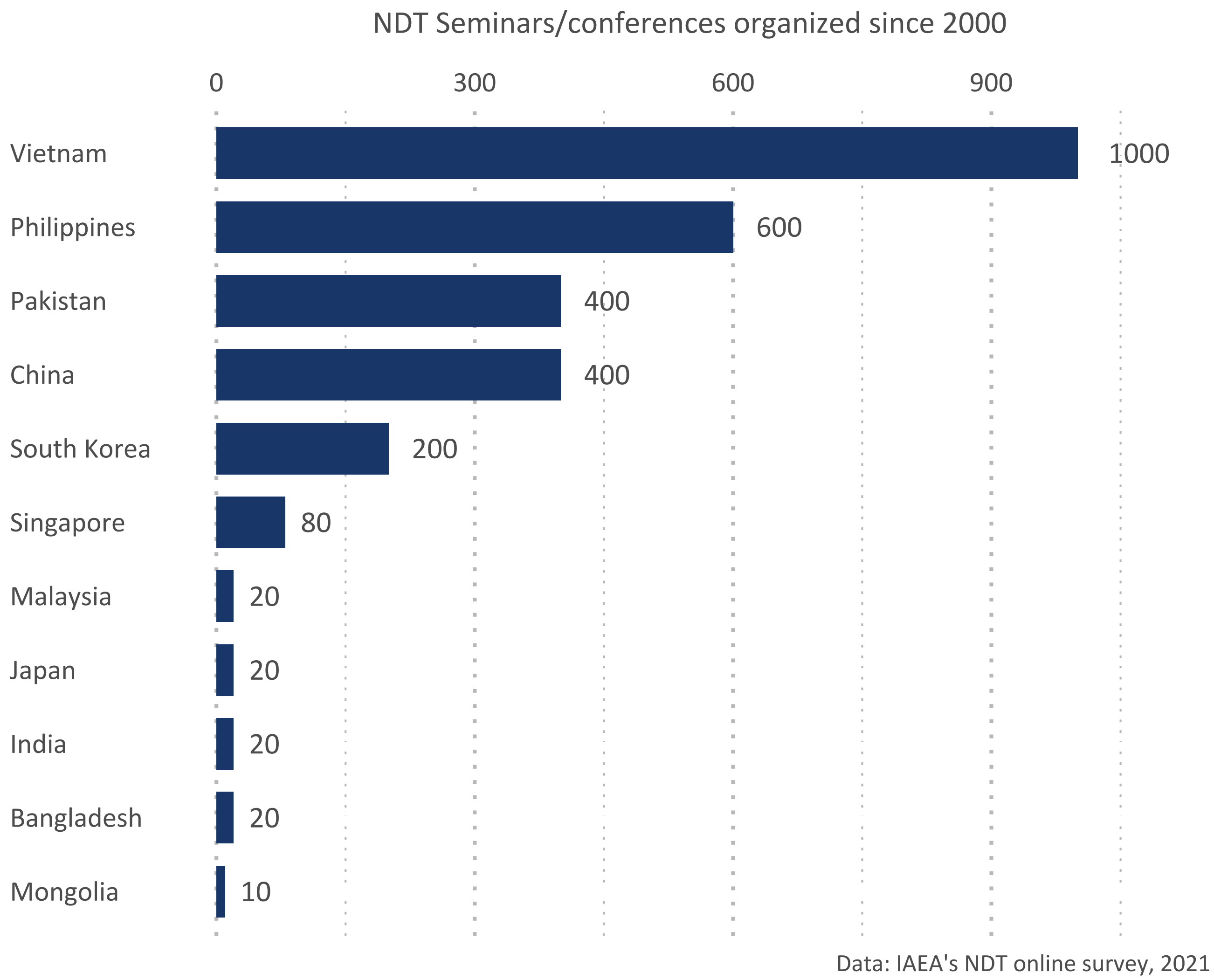


Figure 22: NDT seminars/conferences since 2000

Criterion 3: Improved health and safety

The aim of this section is to understand the extent to which participating in the RCA NDT programme has enabled State Parties to apply NDT technology in the industrial sectors as set by countries' industrial laws for the QA and QC of industrial components, and whether it has resulted in improved health and safety outcomes (i.e. fewer deaths and injuries) and/or reduced environmental pollution.

Key evidence is presented as follows. State Parties were unable to provide estimates for some of the figures requested.

Criterion	Evidence	Finding
Improved health and safety	Per cent of State Parties reporting that the RCA NDT programme contributed to awareness of the benefits of using NDT technologies for safer operations of nuclear and other industrial installations	85%
Improved health and safety	Per cent of State Parties reporting that the RCA NDT programme contributed to applying NDT technologies for safer operation of nuclear and other industrial installations	85%
Improved health and safety	Approximate number of injuries prevented in the industrial sector since 2000 as a result of applying NDT technologies	*State Parties do not have an approximation*
Improved health and safety	Approximate number of deaths prevented in the industrial sector since 2000 as a result of applying NDT technologies	*State Parties do not have an approximation*
Improved health and safety	Approximate reduction of chemical waste (in tonnes) since 2000 as a result of applying NDT technologies	*State Parties do not have an approximation*

Table 5: Key evidence for criterion 3: Improved health and safety

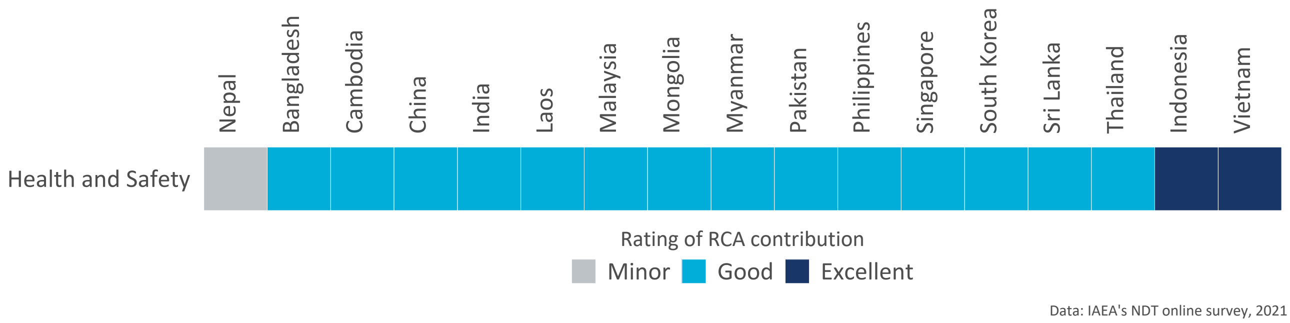


Figure 23: Improved health and safety – rating of RCA contribution

Figure 23 shows the performance standards of the impact of the RCA NDT programme on the Improved health and safety criteria.

The detailed analysis of each sub-criterion under improved NDT capacity and capability is presented in the sections below.

Performance standards of 'Improved Health and Safety'

- **Excellent:** As a result of participation in the RCA program, State Parties have been applying NDT technology in the industrial sectors as set by countries' industrial laws for the QA and QC of industrial components, resulting in improved health and safety outcomes (i.e. fewer deaths and injuries) and/or reduced environmental pollution.
- **Good:** Participation in the RCA program results in State Parties applying NDT technology for safer operation of nuclear and other industrial installations.
- **Adequate:** Participation in the RCA program results in State Parties becoming more aware of the benefits of NDT technology for safer operation of nuclear and other industrial installations.

Figure 24 shows the standards met for this dimension. It is worth mentioning that all the countries except for Vietnam and Indonesia reported that their country does not have an approximation of the reduction of chemical waste, reduced injuries or reduced deaths.

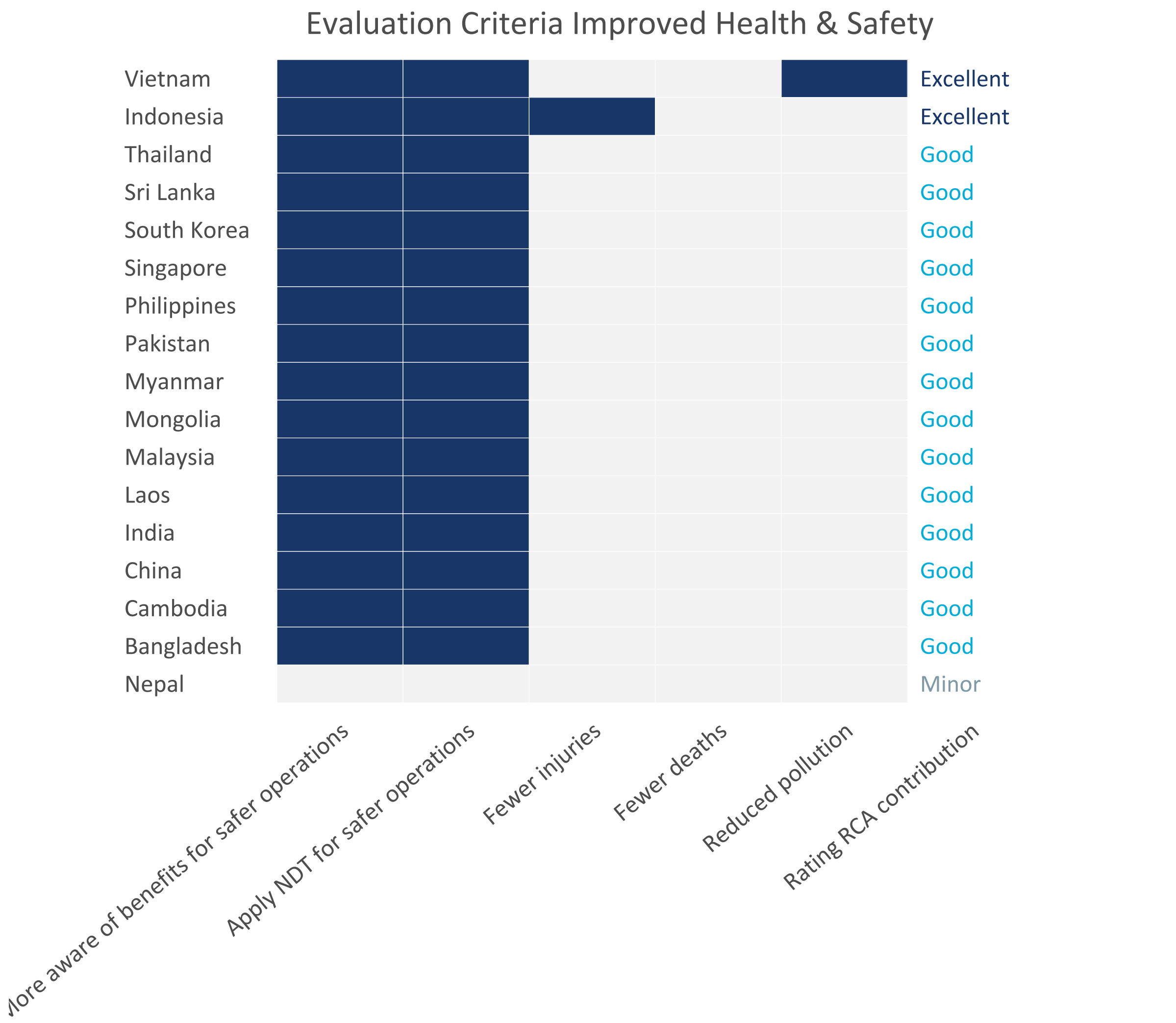


Figure 24: Improved health and safety – performance against standards

Contribution of the RCA NDT programme in improved health and safety

- 85 per cent of all the State Parties reported that being part of the RCA NDT programme contributed to the awareness of the benefits of using NDT technologies for safer operations of nuclear and other industrial installations in their country.
- 85 per cent of all the recipient State Parties reported that being part of the RCA NDT programme contributed to applying NDT technologies for safer operations of nuclear and other industrial installations in their country.
- All State Parties but two reported that their country does not have an approximation of the reduction of chemical waste, reduced injuries or reduced deaths.

Overall impact of the RCA NDT programme

This section aims to summarise the overall role of IAEA/RCA activities in achieving the general objectives and benefits of NDT on socio-economic impact through industrial growth in each State Party that is part of the programme.

Figure 25 shows the perception of the State Party respondents on the role that RCA has had to:

- Help speed up the adoption of NDT technologies since 2000.
- Contribute to the adoption of NDT technologies by private businesses since 2000.
- The productivity of NDT inspections (reduction of the average time to complete an inspection).

According to experts who participated in the online survey, for 83 per cent of the recipient State Parties, the RCA NDT programme has helped speed up the adoption of NDT technologies in their country since 2000. For Bangladesh, India, Indonesia, Laos, Malaysia and Myanmar the adoption occurred one to three years faster. Moreover, China, Mongolia, Pakistan, Philippines, Singapore, Thailand and Vietnam reported that the RCA NDT programme contributed to the adoption of NDT technologies to happen four to five years faster; and South Korea and Sri Lanka considered that the adoption occurred six to ten years faster than without the support of the IAEA.

	Nepal	Australia	Cambodia	Japan	New Zealand	Myanmar	Indonesia	Laos	Mongolia	Bangladesh	India	Malaysia	China	Pakistan	Philippines	Singapore	Thailand	Vietnam	South Korea	Sri Lanka
RCA help speed up adoption						1-3 yr faster	1-3 yr faster	1-3 yr faster	4-5 yr faster	1-3 yr faster	1-3 yr faster	1-3 yr faster	4-5 yr faster	4-5 yr faster	4-5 yr faster	4-5 yr faster	4-5 yr faster	4-5 yr faster	+6yr faster	+6yr faster
RCA help private business adoption							Up to 25%	Up to 25%	51 to 75%	51 to 75%	Up to 25%	Up to 25%	Up to 25%	Up to 25%	51 to 75%	51 to 75%	25 to 50%	25 to 50%	25 to 50%	Up to 25%
RCA increased productivity										10 to 20%		10 to 20%	Up to 10%	10 to 20%	10 to 20%	10 to 20%	+20%	10 to 20%	+20%	10 to 20%

Contribution of RCA in achieving general objectives

N/A No Yes

Data: IAEA's NDT online survey, 2021

Figure 25: Contribution of RCA activities in achieving general objectives and benefits for State Parties

Additionally, 78 per cent of the State Parties reported that the RCA NDT programme contributed to the adoption of NDT technologies by private business in their countries since 2000. From these countries, 50 per cent estimated that the proportion of the total activity in their NDT sector can be attributed to the RCA at least 25 per cent or more.

South Korea, Thailand and Vietnam estimated that between 25 – 50 per cent of total activity in the NDT sector in 2020 can be attributed to the RCA. And Bangladesh, Mongolia, Philippines and Singapore estimated that between 51–75 per cent can be attributed to the RCA.

Finally, Figure 26 shows how every State Party evaluated the role of IAEA/RCA activities in achieving the general objectives and benefits of NDT on socio-economic impact through industrial growth in their country. Their assessment is the following:

- 10 out of the 18 recipient State Parties reported that the role of IAEA/RCA activities in achieving the general objectives and benefits of NDT on socio-economic impact through industrial growth in their countries is excellent.
- 4 of the recipient State Parties and 1 of the non-recipient State Parties (Japan) consider that the role of the RCA NDT programme in achieving the general objectives of NDT in their country is good.
- From the State Parties that consider the RCA did not significantly contribute to their results, two are non-recipient countries (Australia and New Zealand) and one (Cambodia) joint RCA NDT in 2018.

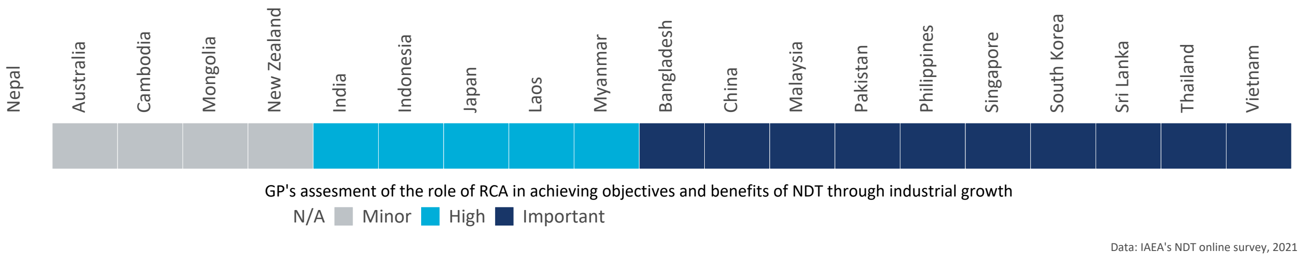


Figure 26: Contribution of IAEA/RCA activities in achieving general objectives and benefit by State Party

Supplementary table: Implementation of NDT technology by industrial sector

The following table provides additional details on the extent to which the introduced NDT technology by the RCA led to improved manufacturing processes, lower production costs, enhanced material quality and greater product integrity in each industrial sector, as was summarised in Figure 17 above.

Country	Industrial Sector	NDT has caused positive improvements in Controlled manufacturing	NDT has caused positive improvements in Ensuring material quality	NDT has caused positive improvements in Greater product integrity	NDT has caused positive improvements in Lower production costs	(%) by which production costs are lower between 2000 and 2020
Australia	Aerospace					
Australia	Chemical					
Australia	Construction					
Australia	Manufacturing					
Australia	Oil and gas					
Australia	Petrochemical					
Australia	Power generation (excluding nuclear)					
Australia	Railway					
Australia	Shipping					
Bangladesh	Aerospace	No	Yes	Yes	No	
Bangladesh	Chemical	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Bangladesh	Construction	No	Yes	Yes	No	
Bangladesh	Manufacturing	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Bangladesh	Nuclear	No	Yes	Yes	No	
Bangladesh	Oil and gas	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Bangladesh	Petrochemical	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Bangladesh	Power generation (excluding nuclear)	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Bangladesh	Railway	No	Yes	Yes	No	
Bangladesh	Shipping	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Cambodia	Construction	Yes	Yes	Yes	No	
Cambodia	Manufacturing	Yes	Yes	Yes	No	
Cambodia	Oil and gas	Yes	Yes	Yes	No	

Table 6: Extent to which the introduced NDT technology by the RCA led to improved manufacturing processes

Country	Industrial Sector	NDT has caused positive improvements in Controlled manufacturing	NDT has caused positive improvements in Ensuring material quality	NDT has caused positive improvements in Greater product integrity	NDT has caused positive improvements in Lower production costs	(%) by which production costs are lower between 2000 and 2020
China	Aerospace	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
China	Chemical	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
China	Construction	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
China	Manufacturing	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
China	Nuclear	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
China	Oil and gas	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
China	Petrochemical	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
China	Power generation (excluding nuclear)	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
China	Railway	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
China	Shipping	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
India	Aerospace	Yes	Yes	Yes	Yes	
India	Chemical	Yes	Yes	Yes	Yes	
India	Construction					
India	Manufacturing	Yes	Yes	Yes	Yes	
India	Nuclear	Yes	Yes	Yes	Yes	
India	Oil and gas	Yes	Yes	Yes	Yes	Small decrease (1% decrease)
India	Petrochemical	Yes	Yes	Yes	No	

Country	Industrial Sector	NDT has caused positive improvements in Controlled manufacturing	NDT has caused positive improvements in Ensuring material quality	NDT has caused positive improvements in Greater product integrity	NDT has caused positive improvements in Lower production costs	(%) by which production costs are lower between 2000 and 2020
India	Power generation (excluding nuclear)	Yes	Yes	Yes	Yes	
India	Railway	Yes	Yes	Yes	Yes	
India	Shipping	Yes	Yes	Yes	Yes	
Indonesia	Aerospace					
Indonesia	Chemical					
Indonesia	Construction					
Indonesia	Manufacturing					
Indonesia	Nuclear					
Indonesia	Oil and gas					
Indonesia	Petrochemical					
Indonesia	Power generation (excluding nuclear)					
Indonesia	Railway					
Indonesia	Shipping					
Japan	Chemical	Yes	Yes	Yes	No	
Japan	Construction	Yes	Yes	Yes	No	
Japan	Manufacturing	Yes	Yes	Yes	No	
Japan	Nuclear	Yes	Yes	Yes	No	
Japan	Oil and gas	Yes	Yes	Yes	No	
Japan	Petrochemical	Yes	Yes	Yes	No	
Japan	Shipping	Yes	Yes	Yes	No	
Malaysia	Aerospace	No	Yes	Yes	No	
Malaysia	Chemical	No	Yes	Yes	No	
Malaysia	Construction	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
Malaysia	Manufacturing	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
Malaysia	Oil and gas	No	Yes	Yes	No	
Malaysia	Petrochemical	No	Yes	Yes	No	
Malaysia	Power generation (excluding nuclear)	No	Yes	Yes	No	
Malaysia	Railway	No	Yes	Yes	No	
Malaysia	Shipping	No	Yes	Yes	No	
Mongolia	Aerospace	No	Yes	Yes	No	
Mongolia	Construction	No	Yes	No	No	

Country	Industrial Sector	NDT has caused positive improvements in Controlled manufacturing	NDT has caused positive improvements in Ensuring material quality	NDT has caused positive improvements in Greater product integrity	NDT has caused positive improvements in Lower production costs	(%) by which production costs are lower between 2000 and 2020
Mongolia	Oil and gas					
Mongolia	Petrochemical	No	Yes	No	No	
Mongolia	Power generation (excluding nuclear)	Yes	Yes	No	No	
Mongolia	Railway	Yes	Yes	No	No	
Myanmar	Construction	No	Yes	Yes	No	
Myanmar	Oil and gas	No	Yes	No	No	
Myanmar	Petrochemical	No	No	Yes	Yes	Small decrease (1% decrease)
Myanmar	Shipping	No	Yes	Yes	No	
Nepal	Construction	No	Yes	No	No	
New Zealand	Aerospace	Yes	Yes	Yes	No	
New Zealand	Chemical	Yes	Yes	Yes	No	
New Zealand	Construction	Yes	Yes	Yes	No	
New Zealand	Manufacturing	Yes	Yes	Yes	No	
New Zealand	Oil and gas	Yes	Yes	Yes	No	
New Zealand	Other	Yes	Yes	Yes	No	
New Zealand	Petrochemical	Yes	Yes	Yes	No	
New Zealand	Power generation (excluding nuclear)	Yes	Yes	Yes	No	
New Zealand	Railway	No	Yes	Yes	No	
New Zealand	Shipping	Yes	Yes	Yes	No	
Pakistan	Manufacturing	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Pakistan	Nuclear	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Pakistan	Oil and gas	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Pakistan	Petrochemical	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Pakistan	Power generation (excluding nuclear)	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
Philippines	Aerospace	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
Philippines	Chemical	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)

Country	Industrial Sector	NDT has caused positive improvements in Controlled manufacturing	NDT has caused positive improvements in Ensuring material quality	NDT has caused positive improvements in Greater product integrity	NDT has caused positive improvements in Lower production costs	(%) by which production costs are lower between 2000 and 2020
Philippines	Construction	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
Philippines	Manufacturing	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Philippines	Oil and gas	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
Philippines	Petrochemical	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Philippines	Power generation (excluding nuclear)	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
Philippines	Railway	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Philippines	Shipping	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
Singapore	Aerospace	Yes	Yes	Yes	No	
Singapore	Chemical	Yes	Yes	Yes	No	
Singapore	Construction	Yes	Yes	Yes	No	
Singapore	Manufacturing	Yes	Yes	Yes	No	
Singapore	Oil and gas	Yes	Yes	Yes	No	
Singapore	Petrochemical	Yes	Yes	Yes	No	
Singapore	Power generation (excluding nuclear)	Yes	Yes	Yes	No	
Singapore	Railway	Yes	Yes	Yes	No	
Singapore	Shipping	Yes	Yes	Yes	No	
South Korea	Aerospace	Yes	Yes	Yes	No	
South Korea	Chemical	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
South Korea	Construction	Yes	Yes	Yes	No	
South Korea	Manufacturing	Yes	Yes	No	No	
South Korea	Nuclear	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)

Country	Industrial Sector	NDT has caused positive improvements in Controlled manufacturing	NDT has caused positive improvements in Ensuring material quality	NDT has caused positive improvements in Greater product integrity	NDT has caused positive improvements in Lower production costs	(%) by which production costs are lower between 2000 and 2020
South Korea	Oil and gas	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
South Korea	Other	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
South Korea	Petrochemical	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
South Korea	Power generation (excluding nuclear)	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
South Korea	Railway	Yes	Yes	Yes	No	
South Korea	Shipping	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
Sri Lanka	Aerospace	No	Yes	No	No	
Sri Lanka	Construction	No	Yes	Yes	No	
Sri Lanka	Manufacturing	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Sri Lanka	Oil and gas	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Sri Lanka	Petrochemical	Yes	Yes	Yes	Yes	Small decrease (1% decrease)
Sri Lanka	Power generation (excluding nuclear)	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Sri Lanka	Shipping	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Thailand	Aerospace	Yes	Yes	Yes	No	
Thailand	Chemical	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Thailand	Construction	Yes	Yes	Yes	No	
Thailand	Manufacturing	Yes	Yes	Yes	Yes	Significant decrease (10% decrease or more)
Thailand	Oil and gas	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)

Country	Industrial Sector	NDT has caused positive improvements in Controlled manufacturing	NDT has caused positive improvements in Ensuring material quality	NDT has caused positive improvements in Greater product integrity	NDT has caused positive improvements in Lower production costs	(%) by which production costs are lower between 2000 and 2020
Thailand	Petrochemical	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Thailand	Power generation (excluding nuclear)	Yes	Yes	Yes	No	
Thailand	Railway	Yes	Yes	Yes	No	
Thailand	Shipping	Yes	Yes	Yes	No	
Vietnam	Aerospace	No	Yes	No	No	
Vietnam	Chemical	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Vietnam	Construction	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Vietnam	Manufacturing	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Vietnam	Oil and gas	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Vietnam	Other	Yes	Yes	Yes	No	
Vietnam	Petrochemical	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Vietnam	Power generation (excluding nuclear)	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Vietnam	Railway	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)
Vietnam	Shipping	Yes	Yes	Yes	Yes	Moderate decrease (5% decrease)

Annex F: Economic Analysis

Summary of findings

We estimated the economic impacts in RCA State Parties of NDT projects under the RCA between 2000 and 2020. Based on results from our survey of NDT experts in RCA State Parties, there is strong evidence that the RCA projects helped to speed up the adoption of NDT in RCA State Parties and facilitated expansion of NDT activities in the private sector. We therefore assume that the growth of NDT activities in RCA State Parties would have been slower between 2000 and 2020 in the absence of the RCA.

Relative to estimated outcomes in RCA State Parties if there was no RCA, under our baseline assumptions we estimate that on average each EUR 1 of costs directly or indirectly associated with the NDT programme of the RCA generated EUR 1.2 of economic benefits, in present value terms from 2000 to 2020. Sensitivity testing reveals that break-even was achieved (i.e., estimated benefits exceeded costs) in 63 per cent of scenarios tested. These scenarios are designed to capture the uncertainty associated with key parameters in our economic model. The estimated benefit-cost ratio was between 0.9 and 1.6 in 50 per cent of scenarios.

Our estimates are conservative in that we have considered only impacts on profits of firms that provide NDT services to customers or that use NDT in-house. We expect that such firms will capture most economic benefits associated with greater use of NDT, but additional benefits may accrue to buyers of NDT services and society more generally that are not included in our model due to the broad nature of these impacts.

Overview of our economic evaluation methodology

Objectives of the economic analysis

We developed a quantitative model to estimate the economic impacts in RCA State Parties attributable to the RCA NDT activities from 2000 to 2020 (inclusive). This includes estimates of:

- economic benefits enabled by RCA NDT activities in RCA State Parties
- economic costs attributable to RCA NDT activities in RCA State Parties, including in-kind contributions to the RCA, opportunity costs and indirect costs associated with participation in the RCA
- direct expenditure by the IAEA on RCA NDT activities

This analysis focuses on the incremental economic impacts that can be attributed to improved collaboration in NDT technologies, as enabled by the RCA. We did not estimate the total benefits and costs of all NDT-related activity in RCA State Parties. Such benefits are expected to be larger than the incremental impacts of the RCA on adoption and use of NDT, but most such benefits cannot be attributed to the RCA.

The economic analysis is also targeted at assessing the RCA against the agreed evaluation rubric for economic value. This requires evaluating how likely it is that the RCA created more value than it consumed (i.e., whether break-even was achieved in terms of economic benefits created compared to economic costs incurred).

Modelling economic impacts of the RCA NDT programme

NDT is used in a wide variety of industries including energy, petrochemical and chemical manufacturing, rail, sea and aerospace transport, construction and nuclear energy. Within each of these industries, various NDT techniques can be used in many different applications, depending on the types of objects that need to be tested, what these objects are made from, the frequency and objectives of testing and other practical considerations.

Given the variety of testing techniques and the broad nature of NDT applications, it is challenging to produce a bottom-up estimate of the overall economic benefits of the RCA NDT programme as this requires detailed modelling of benefits and costs of individual applications in each RCA State Party. Instead, our economic methodology reflects the diversity of NDT technologies and uses the fact that NDT services are generally provided by private-sector firms either as a service to other firms or in-house.

We make use of the fact that firms using NDT or providing it as a service will capture some of the economic benefits of NDT in the form of their profits. To the extent that the RCA NDT programme activities promote the adoption and use of NDT by firms in RCA State Parties, the RCA is also expected to increase the scale of NDT activity and associated profits earned by firms. By analysing such changes in profits, we can understand the economic impact of the RCA NDT programme in proportion to changes in profits that can be attributed to RCA activities.

We define the NDT industry in a country as those firms that provide NDT services, as well as the in-house provision of NDT within larger organisations. In the case of in-house provision of NDT, it is difficult to separate testing activities from other activities of the business. In such cases we assume for modelling purposes that NDT is effectively provided by an external firm that provides the same type and scale of NDT as is provided in-house.[15]

High-level effects of the RCA on economic activity

Under the RCA, the IAEA and State parties invest in various activities designed to promote improved NDT capability in RCA State Parties. This may also trigger complementary investment in NDT facilities by private businesses. Via these activities, the RCA is expected to assist with establishing NDT infrastructure and help to increase the number of people certified in NDT techniques. In addition, the RCA aims to promote:

- Awareness of the benefits of using NDT for production quality and efficiency;
- Local and regional capability in industrial applications of NDT and associated research and development activities; and
- Greater awareness of the benefits of NDT technology for increasing safety.

Such activities are expected to lead to increased adoption and use of NDT in RCA State Parties, and available data indicates that use of NDT in RCA State Parties has increased substantially over time. Based on survey information provided by NDT experts

15 Implicitly we assume that a profit-maximising firm would only do NDT in-house if it is indifferent between that and purchasing NDT services from an external provider. We therefore assume that the contribution of in-house NDT to a firm's profit is equal to the profit that would be made by an external provider of those services to the firm. This is a conservative assumption because firms will not do NDT in-house if they estimate that doing so is less profitable than using an external provider. Thus, profits from in-house NDT will be equal to or greater than buying NDT services from other firms.

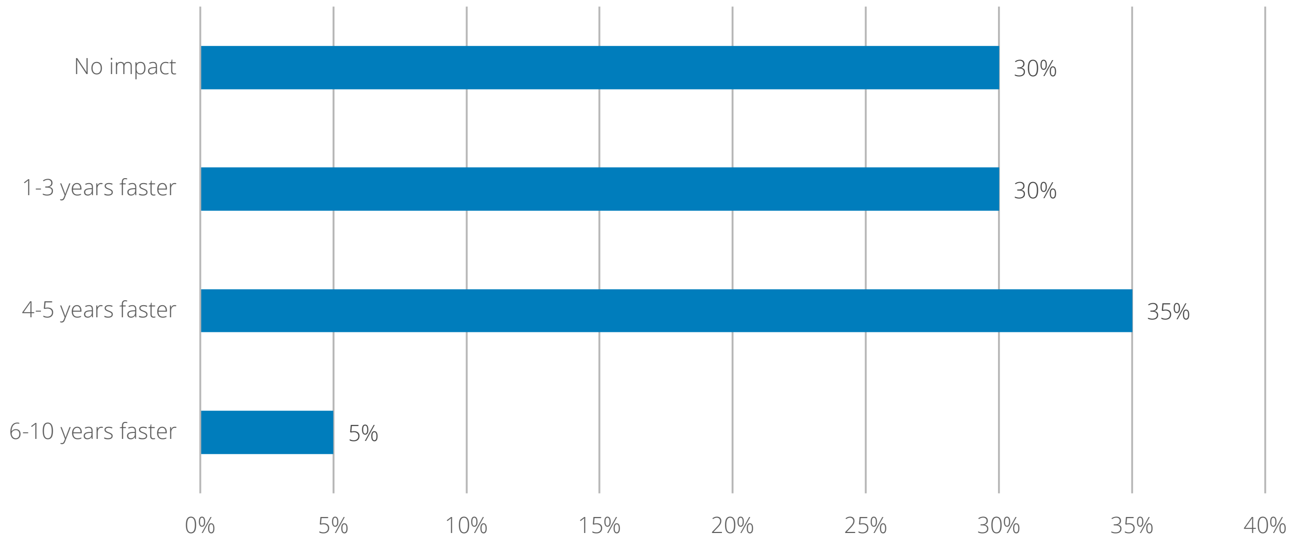


Figure 27: Reported impact of RCA activities on adoption of NDT technologies in RCA State Parties. Source: Online survey of experts from RCA State Parties.

in RCA State Parties, total nominal revenues of NDT inspection companies increased from EUR 86m in 2000 to EUR 318m in 2020 (a compound annual growth rate of 6.8 per cent).

The reported number of private sector NDT inspection companies in RCA State Parties also increased by 113 per cent from 1 262 to 2 694 over the same period.

Respondents to our survey indicated that in many cases the RCA helped to speed up the adoption of NDT technologies in RCA State Parties. This implies that the growth in economic activity associated with NDT between 2000 and 2020 would have been smaller in the absence of the RCA. Across RCA State Parties that responded to our survey, 70 per cent reported that the RCA had helped to speed up the adoption of NDT to some extent (Figure 27). Most of these RCA State Parties reported that adoption of NDT technologies was between one and five years faster than it would have been without the RCA.

As well as speeding up adoption, 45 per cent of RCA State Parties that responded to the survey indicated that RCA activities helped to improve the productivity of NDT inspections. Most RCA State Parties that reported a productivity improvement indicated that average inspection times reduced by between 10 per cent and 20 per cent due to the RCA (Figure 28).

In addition, of RCA State Parties that responded to the survey:

- 72 per cent indicated that the RCA contributed to support the adoption of NDT technologies by private businesses;
- 53 per cent indicated that the RCA helped to facilitate investment in NDT inspection facilities; and
- 50 per cent indicated that the RCA helped to facilitate the establishment of local NDT inspection companies ‘to a great extent’, and a further 22 per cent indicated that the RCA helped to a ‘little’ extent.

In combination, the above findings give good evidence that RCA activities contributed to an expansion of NDT activities in RCA State Parties. Our economic analysis seeks to estimate some of the economic impacts associated with NDT inspection activities arising from the greater volume and productivity of such activities under the RCA.

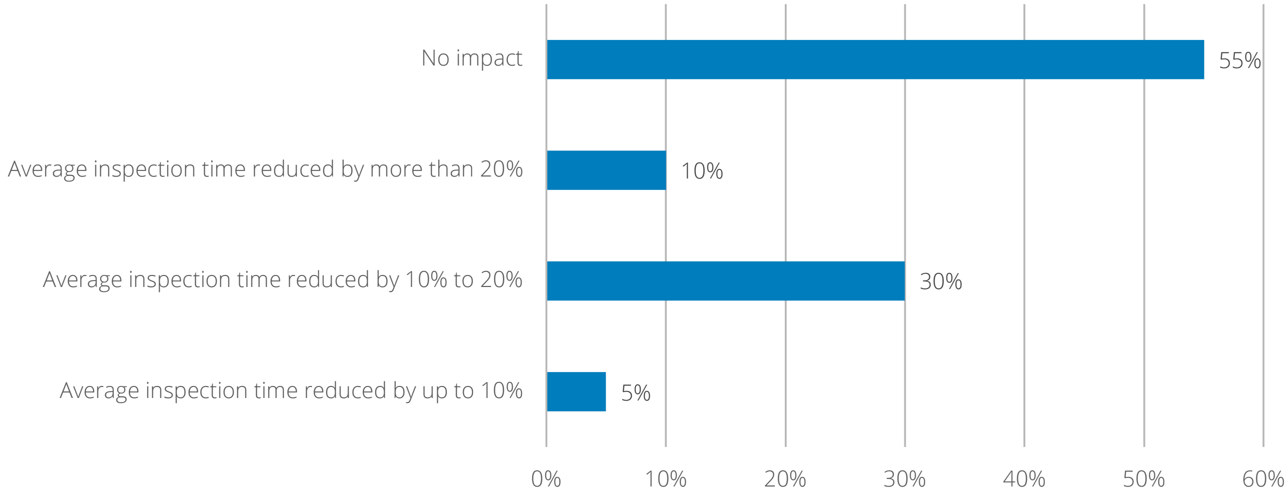


Figure 28: Reported impact of RCA activities on productivity of NDT inspections. Source: Online survey of experts from RCA State Parties.

Modelling economic benefits and costs of the RCA

This section summarises the methods, data sources and assumptions used to model the economic impacts of the RCA NDT programme activities across RCA State Parties.

Modelled scenarios

Our economic analysis is based on a retrospective comparison of two scenarios for the use of NDT across all RCA State Parties for the period from 2000 to 2020:

1. *Factual scenario:* This reflects actual outcomes for the use of NDT in RCA State Parties between 2000 and 2020 (i.e., outcomes that occurred under the RCA).
2. *Counterfactual scenario:* This reflects hypothetical outcomes for the use of NDT that we estimate would have occurred in RCA State Parties between 2000 and 2020 in the absence of the RCA. Given the survey findings reported above, we assume that this involves a lower level of NDT activity in RCA State Parties in any given year compared to the factual scenario for that State Party in the same year.

Estimated economic outcomes associated with these two scenarios are compared for each RCA State Party individually and the results are aggregated to obtain total estimated impacts of the RCA between 2000 and 2020. The economic analysis focuses on estimating the incremental impacts of the RCA (i.e., the differences between the factual and counterfactual scenario). Given that we have observed actual outcomes under the factual scenario, the hypothetical counterfactual scenario is modelled relative to these actual outcomes. Results for each of these two scenarios are also generated under various alternative assumptions to test the sensitivity of the results (see below).

Modelling economic benefits of RCA activities

Accelerated adoption of NDT

Based on responses to our survey, most RCA State Parties reported that the RCA helped to speed up adoption of NDT technologies (see Figure 27 above) and some State Parties reported that the RCA also helped to improve the productivity of NDT inspections (see Figure 28 above). For each State Party that reported faster adoption of NDT under the RCA, we estimate the number of licensed NDT inspectors directly and indirectly trained due to the RCA in each year and assume that these inspectors were trained sooner than they otherwise would have been in the counterfactual scenario. That is, we assume that the RCA helped to bring forward adoption and use of NDT that would otherwise have occurred in the counterfactual but at a slower pace.

In total between 2000 and 2020, data provided by the IAEA indicates that 398 people were trained in NDT in RCA State Parties. In addition, respondents to our survey indicated that 2,634 people were directly or indirectly trained under the RCA between 2000 and 2020 (including in-country activities that could be linked to RCA activities or indirectly enabled by the RCA). We do not know when these additional 2,236 people were trained, but we assume this occurred over time in proportion to the number of people directly trained under the RCA.

We use each RCA State Party's response to the survey question about the impact of the RCA on speeding up NDT adoption to estimate how many people would have been trained in NDT in the counterfactual in each RCA State Party in each year. This involves shifting forwards in time the number of people who were trained under the RCA so that they are trained in a later year in the counterfactual. The results of this modelling are shown in Figure 29, which shows the total number of NDT inspectors trained directly or indirectly under RCA, and the result of assuming that some of these inspectors were trained at a later date under the counterfactual.

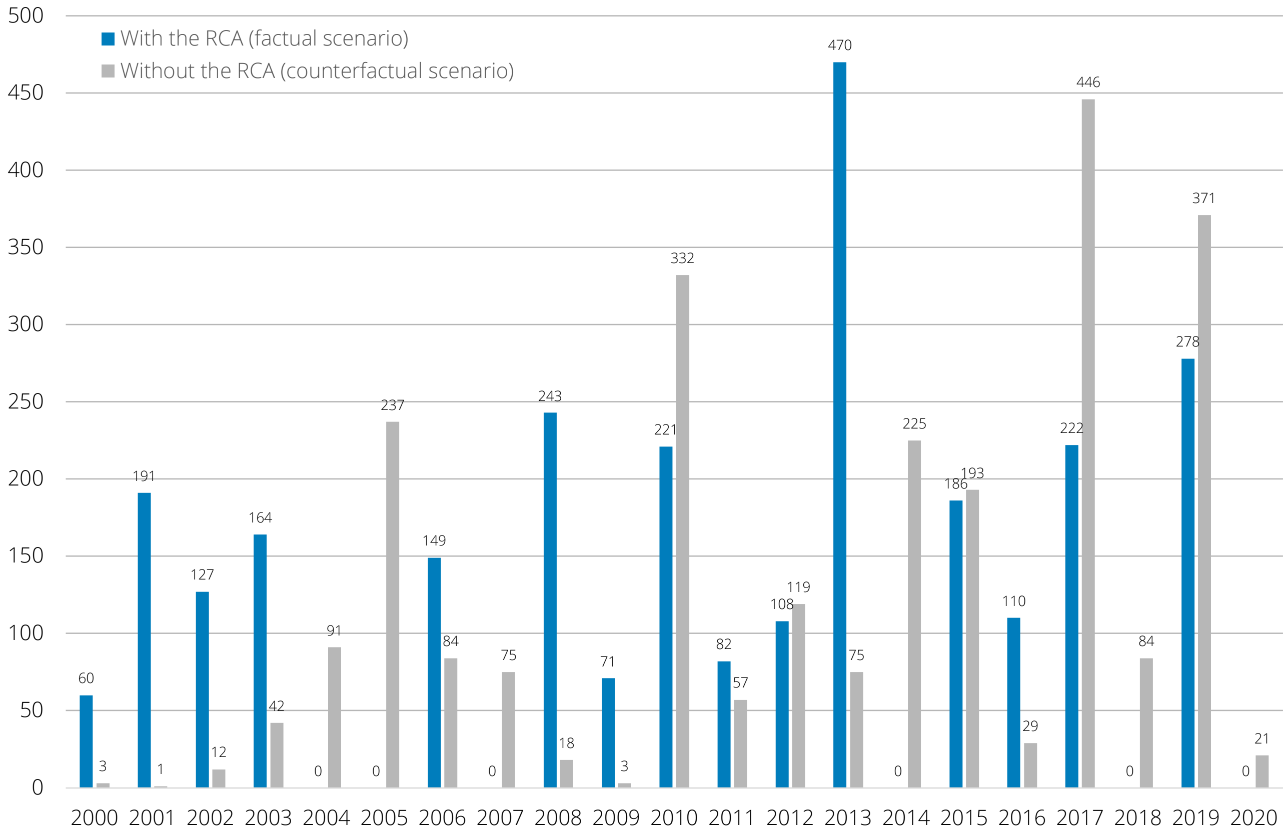


Figure 29: Modelled number of additional NDT inspectors in RCA State Parties trained in each year under the RCA and counterfactual scenarios, with baseline assumptions. Source: Calculated.

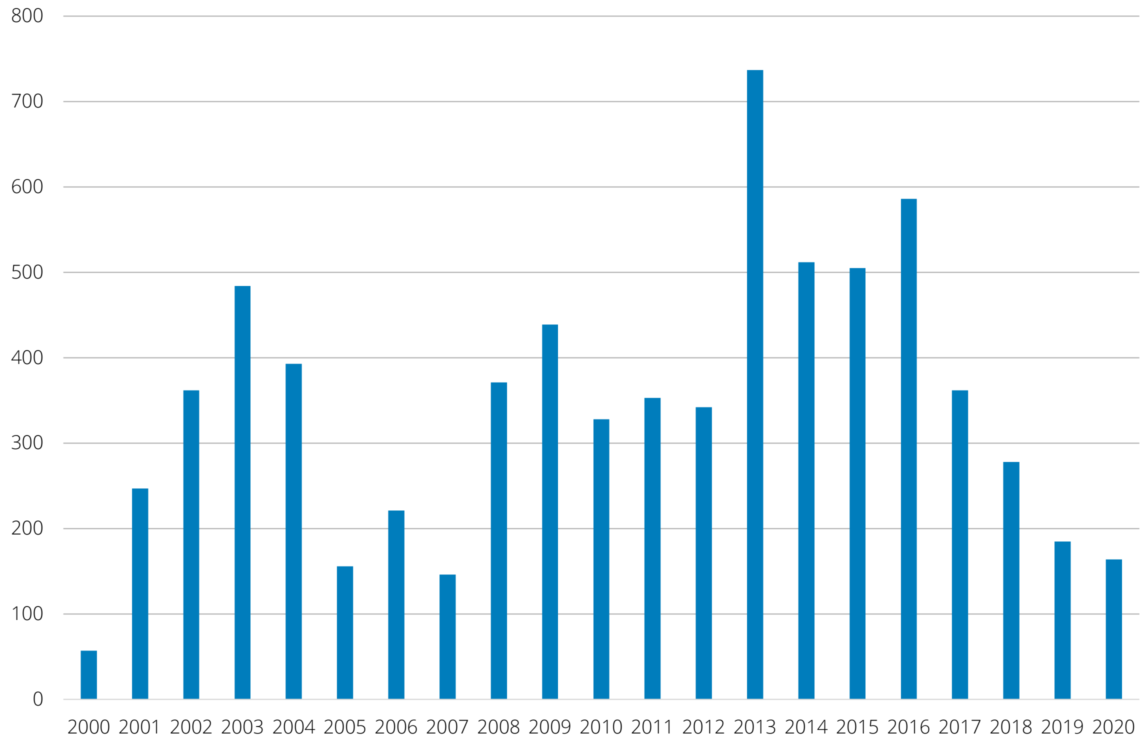


Figure 30: Estimated additional NDT inspectors in RCA State Parties in each year under the RCA compared to the counterfactual, under baseline assumptions. Source: Calculated.

Figure 30 shows the resulting modelled number of additional NDT inspectors under baseline assumptions in total, under the RCA relative to the counterfactual. The amount varies by year depending on the number of people trained under the RCA and the extent to which each State Party indicated that the RCA speeded up adoption of NDT. On average across all years and all RCA State Parties, we estimate there were an additional 344 NDT inspectors with the RCA compared to the counterfactual. We also test alternative assumptions about the extent to which the RCA speeded up adoption of NDT technologies in each RCA State Party (sensitivity analysis is discussed below).

Economic benefits of accelerated adoption

The additional NDT inspectors in RCA State Parties due to accelerated adoption of NDT under the RCA are assumed to lead to increased NDT activities relative to the counterfactual in any given year. As explained above, we measure the economic benefits of this increased activity by estimating the increase in profits associated with NDT inspections. The change in profits is calculated by multiplying the number of additional NDT inspectors with the RCA compared to the counterfactual (Figure 30 above) by the estimated number of working hours per inspector per year, the average price per hour of NDT inspections, and profits as a proportion of revenues for NDT activities.[16] Data on the following factors in this calculation was obtained from our survey of NDT experts in RCA State Parties:[17]

16 We assume that the profit ratios reported in the survey correspond to net profits after all expenses including depreciation are accounted for. Depreciation reflects an accounting allocation of capital costs over time and as such is not an economic cost, so we adjusted the reported profit ratios by adding back an estimated 5 per cent to reflect depreciation as a proportion of revenues. We account for incremental capital costs attributable to the RCA NDT programme separately, as described below.

17 Member states that did not respond to the relevant questions in the survey were assigned the median value across member states that did respond.

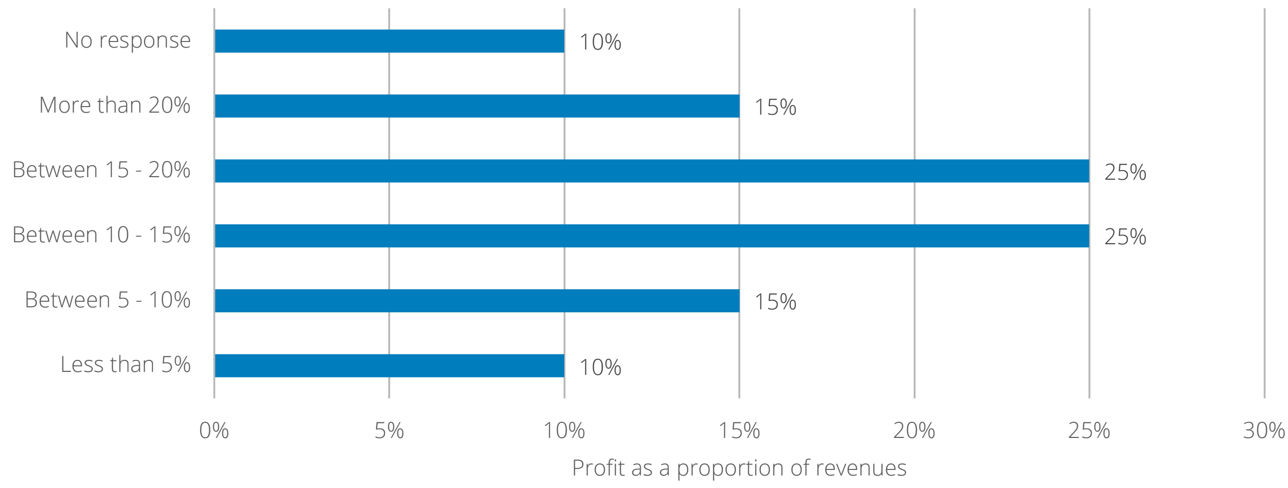


Figure 31: Profits as a proportion of revenues for NDT inspection activities, in RCA State Parties. Source: Online survey of experts from RCA State Parties.

- Typical working hours per NDT inspector per year (median 1,200 hours across all RCA State Parties)
- Average price per hour of NDT inspections (median EUR 21/hour across all RCA State Parties)
- Profits as a proportion of revenues for NDT activities (Figure 31 below)
- Impact of the RCA on productivity of NDT inspections (Figure 28 above)

The above assumptions, applied to each RCA State Party using their individual responses to relevant questions in the survey, gives the estimated annual additional profits from NDT activities in State Parties shown in Figure 32. These are estimates of incremental profits attributable to the RCA, due to accelerated adoption of NDT in RCA State Parties. Under baseline assumptions, these incremental profits total EUR 13.1m in present value terms from 2000 to 2020.

Unquantified benefits of the RCA

Our analysis focuses on economic impacts as measured by increased profits from NDT services, enabled by accelerated adoption of NDT in RCA State Parties. We acknowledge that profits are usually only part of the economic benefits associated with an activity, and economic benefits may also be obtained by the buyers or users of NDT services, to the extent that the price actually paid is less than the value to the buyer (or the buyer's willingness to pay).

This 'consumer surplus' is not captured in our economic model because we do not have sufficient information to estimate the value of NDT services to buyers. To the extent that expanded NDT activities under the RCA lead to consumer surplus as well as additional profits, our model will understate the total economic benefits of RCA activities.

Modelling economic costs of RCA activities

The following economic costs attributable to the RCA NDT programme were modelled:

- Monetary and opportunity costs of RCA State Parties and the IAEA that are directly associated with RCA activities
- In-kind (non-monetary) contributions of RCA State Parties to support RCA activities

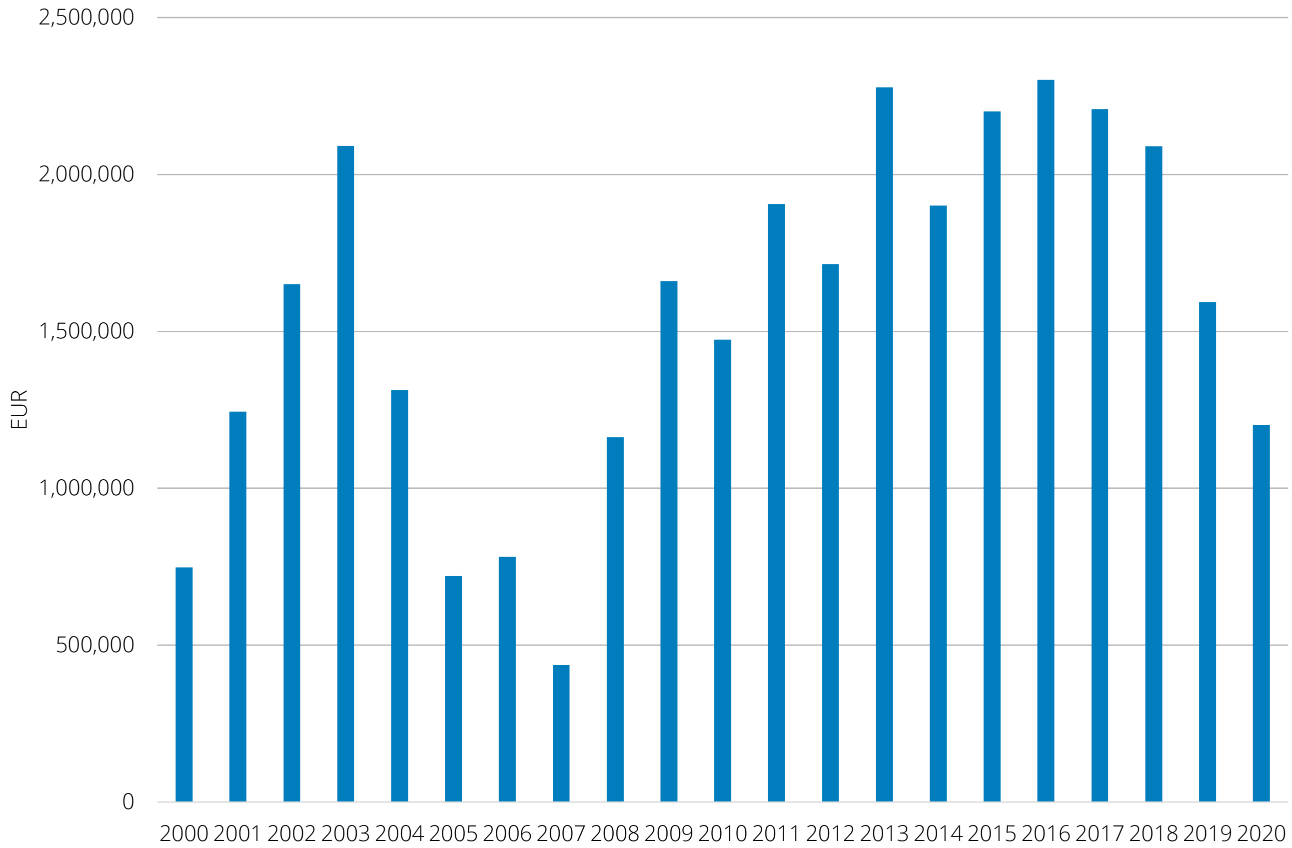


Figure 32: Estimated additional profits from NDT inspection activities in RCA State Parties in each year under the RCA compared to the counterfactual, under baseline assumptions. Source: Calculated

- Capital costs associated with expanded NDT activities (relative to the counterfactual) in RCA State Parties that can be attributed to RCA activities

Direct costs of RCA activities
Direct costs include costs of RCA NDT activities such as organising and participating in RCA meetings, scientific visits, expert missions, fellowships, and training courses. This includes:

- Costs directly incurred by the IAEA to support these activities
- Opportunity costs of time for attendees of RCA activities from RCA State Parties

Annual direct costs incurred by the IAEA from 2000 to 2020 were estimated based on information provided by the IAEA about the type and number of activities under the RCA NDT programme, and the costs of these activities (Table 7).[18] Including a 10 per cent increment for overhead costs, we estimate that total direct costs incurred by the IAEA for the RCA NDT programme amounted to around EUR 1.9m from 2000 to 2020, or around EUR 858 000 in discounted present value terms.

18 Cost information was only available for years from 2011 to 2020. Average costs per activity calculated from these years were applied to activities that took place from 2000 to 2010.

Activity	Average cost (EUR)	No. of activities	No. of participants
Training course	41 780	20	398
Expert mission	6 890	22	27
Meeting/ workshop	37 953	20	325

Table 7: Estimated direct costs incurred by the IAEA per activity between 2000 and 2020. Source: Calculated from data provided by the IAEA.

Opportunity costs of time for attendees to RCA training courses and meetings or workshops are estimated assuming a 14-day duration for training courses and 7 days for other activities (including travel time). Costs for participants are estimated based on real GDP per capita in each RCA State Party, multiplied by a premium for skilled labour calculated from International Labour Organisation data. In total across RCA State Parties, under our baseline assumptions we estimate the discounted present value of such opportunity costs was around EUR 216 000 from 2000 to 2020.

Costs of in-kind contributions from RCA State Parties

We understand that RCA State Parties contribute to the cost of RCA activities by providing 'in-kind' services such as the use of conference facilities, and administrative staff time. The value of these in-kind contributions is estimated based on averages provided by the IAEA:

- Training course hosting: EUR 1600 per day
- Non-training activity hosting: EUR 800 per day
- Staff cost for training or expert missions: EUR 160 per day

Under these assumptions and based on activity data provided by the IAEA, under our baseline assumptions we estimate the total discounted present value of in-kind contributions of RCA State Parties was around EUR 242 000 from 2000 to 2020.

Indirect costs of expanded NDT activities in RCA State Parties

RCA activities are assumed to lead to accelerated expansion of NDT activities in RCA State Parties, as explained in the description of the modelled economic benefits above. This means that, in any given year, the number of licensed NDT inspectors and the corresponding volume of NDT-related economic activity in RCA State Parties is greater under the RCA than it would have been in the counterfactual scenario.

Our economic model assumes that each additional licensed NDT inspector in an RCA State Party in a year (relative to the counterfactual in that year) attributable to RCA activities also requires some investment in additional capital equipment necessary to carry out NDT inspections. This capital investment is not directly funded by the RCA, but it is effectively brought forward in time under the RCA due to accelerated uptake of NDT. This change in timing of capital costs can be attributed to the RCA and is captured in our economic model.

To estimate these impacts on NDT capital costs in RCA State Parties, we used National Accounts data from the OECD to model the relationship between real GDP per capita and gross fixed assets per employee in professional, scientific and technical activities. This relationship as estimated across OECD countries is shown in Figure 33, and was used to estimate incremental capital investment required for each additional licensed NDT inspector in RCA State Parties. Across State Parties, the estimated incremental capital required per additional licensed NDT inspector ranges from around EUR 26 000 to EUR 320 000, with a median of around EUR 32 500.

In total from 2000 to 2020, we estimate that the RCA was associated with EUR 9.8m of incremental capital costs in RCA State Parties between 2000 and 2020 in discounted

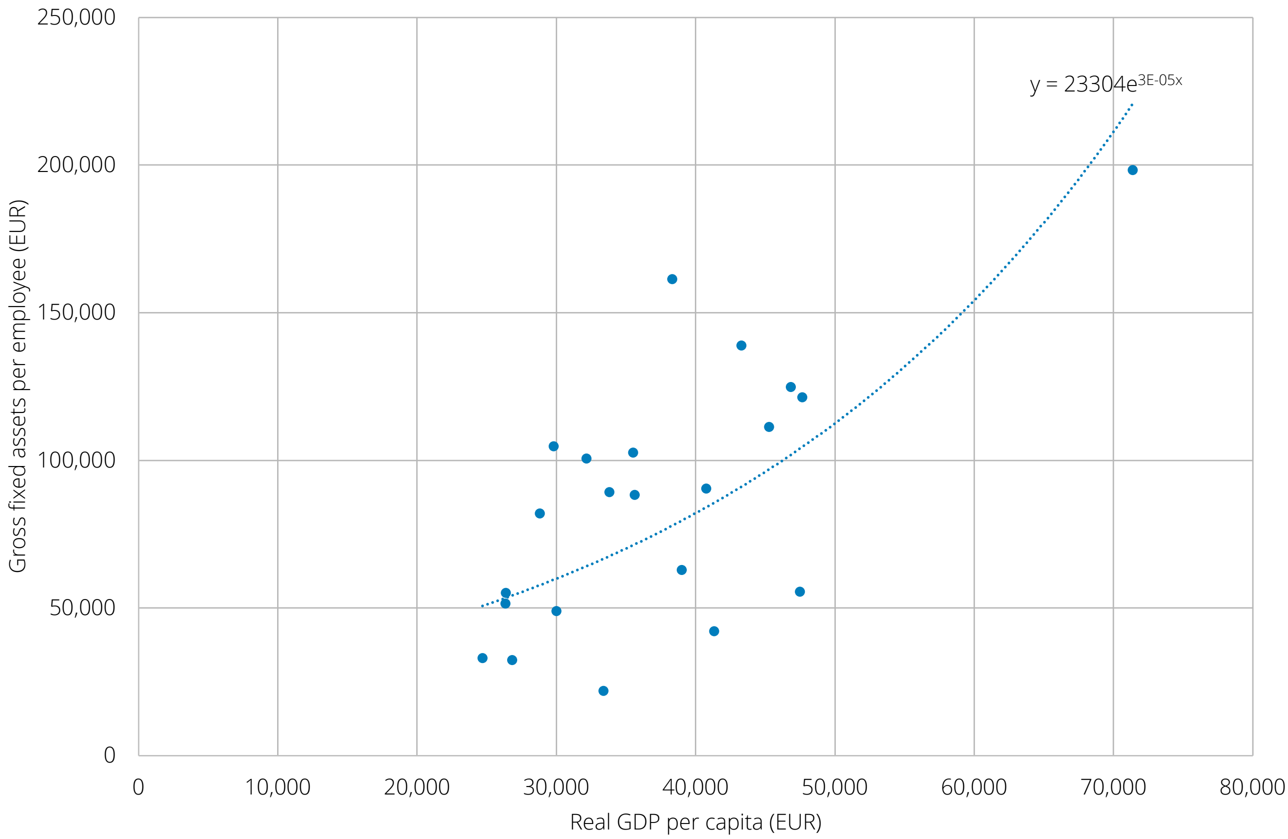


Figure 33: Estimated relationship between real GDP per capita and gross fixed assets per employee in professional, scientific and technical activities in OECD countries. Source: Calculated from OECD National Accounts data.

present value terms. This reflects economic costs associated with changes in the timing of costs of NDT capital equipment in State Parties that can be attributed to the RCA.

Outputs of the economic model

Benefit-cost ratio

The primary output of the economic model is an average benefit-cost ratio (BCR) across all RCA State Parties from 2000 to 2020. This BCR reflects the average benefits attributable to the RCA for each EUR 1 of costs that are directly and indirectly attributable to the RCA. The BCR is calculated as the ratio of the present value of economic benefits attributable to the RCA to the present value of economic costs attributable to the RCA, across all RCA State Parties. A BCR greater than one indicates that estimated benefits of the RCA exceed its costs.

We focus on this average BCR rather than the absolute value of estimated net economic benefits (i.e. benefits minus costs) as the methodology for estimating benefits focusses on profit impacts and is unlikely to capture all economic benefits of the RCA. This approach is designed to evaluate the performance of the RCA against the economic rubric that was defined for this evaluation (Table 12, Annex G) while recognising that the estimated economic benefits are likely understated.

It is important to note that the estimated BCR is an average effect across RCA State Parties for the historic activities from 2000 to 2020. We have not estimated the potential impacts of expanding or reducing the scale of RCA activities, and the estimated BCR should not be used to guide future decisions about RCA activities. Instead, the estimated BCR reflects average economic performance of the actual RCA activities between 2000 and 2020.

Discounting and the discount rate
This cost-benefit analysis is retrospective and estimates economic benefits and costs that have already occurred. The usual practice in a forward-looking social cost-benefit analysis is to discount future outcomes by a multiple that depends on a social discount rate and how far into the future these outcomes occur.[19] In forward-looking social cost-benefit analysis, the justification for such discounting is that there is uncertainty about whether future outcomes will occur, which means benefits and costs that occur now have greater value than those that occur in the future.

In a retrospective cost-benefit analysis there is no uncertainty about whether outcomes will occur. However, to be consistent with the justification for discounting in a social cost-benefit analysis, it is necessary to carry out a retrospective analysis as if it were a forward-looking analysis and to discount benefits and costs over time in the same way. In addition, capital invested in NDT activities in State Parties due to the RCA could have been put to alternative uses and this generates opportunity costs. For these reasons, our analysis discounts all benefits and costs incurred between 2000 and 2020 back to the year 2000. For ease of interpretation, we express all benefits and costs in real 2020 euros.

Our analysis uses a baseline discount rate of 10.2 per cent (low scenario 5.2 per cent, high scenario 15.2 per cent) for benefits and costs that occur between 2000 and 2020. The baseline discount rate was set by assigning the RCA State Parties to low-, medium-, and high-risk categories and assuming discount rates of 5 per cent, 10 per cent, and 15 per cent respectively.

Discounting has complex effects on the net present value of economic benefits attributable to the RCA. Discounting reduces the present value of future benefits, as explained above. However, some of the benefits of the RCA are due to bringing forward the benefits of NDT in some State Parties, and these benefits are greater when the discount rate is higher. Thus, increasing the discount rate has two offsetting effects on the present value of the estimated benefits of the RCA NDT programme. This means that the net present value of the estimated economic impacts does not necessarily decrease when the discount rate increases.

Summary of key assumptions and sensitivity testing

Table 8 summarises the key parameters of the economic model, including baseline values and low and high alternatives used for sensitivity testing. Two types of sensitivity testing were performed:

1. Setting each parameter at its alternative low and high values while maintaining all other parameters at their baseline values. This helps to reveal the sensitivity of the results to changes in each individual parameter.
2. Generating results across all combinations of the three alternative values for each of the parameters in Table 8 (a total of 177 147 combinations). This gives the potential overall range of results assuming it is equally likely that each parameter could take its low, baseline or high value.

19 Specifically, the discounted value of a benefit or a cost x that occurs t years in the future given a social discount rate of r is x / (1 + r)t.

Parameter	Low scenario	Baseline value	High scenario
Discount rate (real)	5.2%	10.2%	15.2%
Overhead costs of RCA activities as a proportion of direct costs	5.0%	10.0%	20.0%
Depreciation as a proportion of revenue for NDT services	3.0%	5.0%	7.0%
RCA NDT programme workshop duration (days incl. travel time)	5	7	9
RCA NDT programme expert mission duration (days incl. travel time)	5	7	9
RCA NDT programme training course duration (days incl. travel time)	12	14	16
Extent of accelerated adoption of NDT due to the RCA (years)*	1.2	1.8	2.4
Working hours per NDT inspector per year*	895	1 194	1 492
Average price per hour of NDT inspection (EUR)*	22	29	36
NDT services profits as a proportion of revenue*	11.4%	14.2%	18.2%
Productivity impact of the RCA on NDT inspections*	4.1%	6.1%	8.2%

Table 8: Summary of parameters of the economic model.

Baseline and scenario values shown are averages across RCA State Parties. The model uses different values for these parameters for each State Party, based on survey responses.

Results from the economic analysis

Baseline result

In the baseline scenario as described above, we estimate that RCA NDT activities had a benefit-cost ratio of 1.2 between 2000 and 2020. This means that on average each EUR 1 of additional economic costs directly or indirectly attributable to the RCA was associated with EUR 1.2 of additional economic benefits. This is an average estimate for the period of this evaluation and does not imply that any future expansion of the RCA would cause a similar expansion of economic benefits as was estimated for historic activities.

Sensitivity testing

Figure 34 summarises the results of testing the sensitivity of the model results to changes in each of the model parameters individually while keeping all other parameters at their baseline values. This shows that the results are relatively sensitive to changes in the discount rate, which reflects the fact that main impact of RCA activities is to accelerate adoption of NDT technologies in State

Parties. This creates economic impacts due to changes in the timing of NDT activities and associated profits and capital expenditures.

The results are also somewhat sensitive to changes in the assumptions used to estimate profits from NDT activities, i.e. the profit rate, price per hour, and working hours assumptions. The results are relatively insensitive to the parameters reflecting costs of the RCA (e.g. workshop and training course durations) and the extent to which the RCA speeded up adoption of NDT.

Across all 177 147 combinations of low, baseline, and high values of the parameters shown in Table 8, the estimated BCR was greater than one (i.e. break-even was achieved) in 63 per cent of scenarios tested and the median BCR across all scenarios was 1.2. Estimated BCRs ranged from 0.3 to 3.7 overall, with 95 per cent of estimated values falling between 0.5 and 2.7, and 50 per cent of estimated BCRs falling between 0.9 and 1.6.

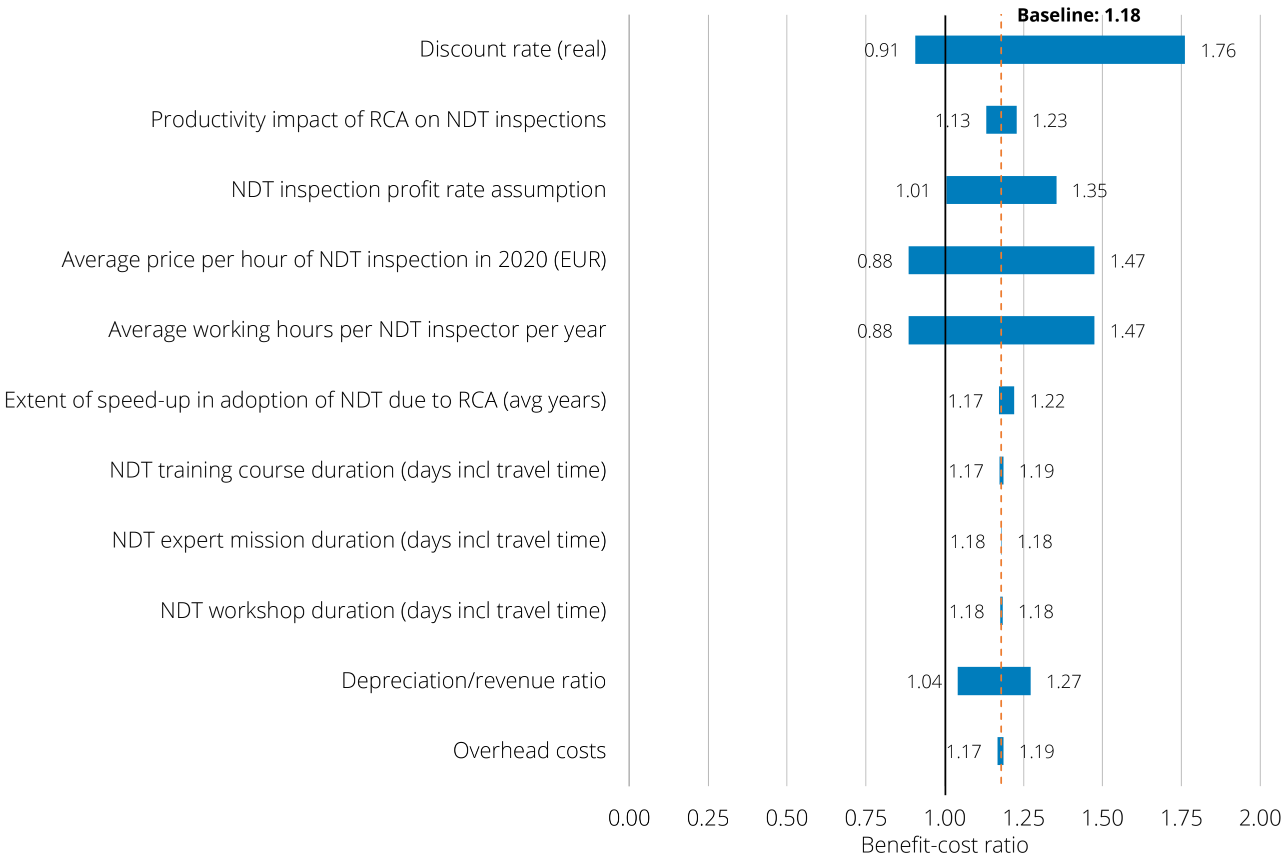


Figure 34: Sensitivity of estimated BCR to changes in individual model parameters.

Annex G: Methodology

The social and economic impact assessment methodology was developed specifically for IAEA, for case studies of Technical Cooperation (TC) projects under the Regional Cooperative Agreement for Research, Development and Training Related to Nuclear Science and Technology for Asia and the Pacific (RCA). The methodology follows the *Value for Investment* approach developed by Dr Julian King (King, 2017; King, 2019; King & OPM, 2018) and the Kinnect Group approach to evaluation rubrics (King et al., 2013; McKegg et al., 2018).

Evaluating impact in complex environments

From the outset it was acknowledged that these case studies would be challenging to conduct. The RCA is a complex environment for evaluation. There are diverse countries and stakeholder groups, long-term investments of decades with contexts that are continuously evolving and multiple outcomes sought across a range of thematic areas. Impact evidence has not been routinely collected; TC outcome monitoring systems have generally focused on immediate outcomes and have not included longer-term social and economic impacts.

Developing the methodology

A meeting was held in Vienna, Austria from 1–4 July 2019 to establish a methodology and work plan for performing the case studies. The meeting had eight participants including representatives from TCAP, TCPC, and invited experts from China and New Zealand. Invited experts, Dr Julian King and Kate McKegg, summarised and compared approaches and tools for social and economic impact assessment. A methodology was proposed – *Value for Investment* – that combines strengths from the disciplines of economics and evaluation.

A methodology was needed that could:

- Evaluate impacts retrospectively, looking back many years
- Evaluate long-term effects, because there is often a long lag between project completion and the realisation of social and economic impacts
- Capture unexpected outcomes, instead of just looking for the expected outcomes, because these can be as impactful as the project's originally stated target outcomes
- Measure the intangible value of the RCA's contributions, such as networking, in addition to outcomes that are more amenable to numeric and/or monetary metrics
- Deal with the complexity of attribution (or at least contribution), recognising that one outcome can arise from many contributions (of which the RCA project may be only one) and conversely one project may contribute to many different outcomes or impacts.

Evaluation is the systematic determination of the merit, worth or significance of something. Evaluation of social and economic impacts requires not only *evidence* of those impacts, but also *valuing* – interpreting the evidence through the lens of what matters to people (King, 2019). Economics and evaluation bring different approaches to valuing. For example, cost-benefit analysis uses money as the metric for understanding value (Drummond et al., 2005), while other approaches include numerical or qualitative synthesis (Davidson, 2005) or citizen deliberation (Schwandt, 2015).

The *Value for Investment* approach combines approaches to valuing from evaluation and economics. It accommodates multiple values (e.g., social, cultural, environmental and economic) and multiple sources of evidence (qualitative and quantitative) to enable robust and transparent ratings of the RCA's impacts. The approach involves eight steps:

1. Understand the programme or project, including its context, stakeholders and theory of change.
2. Develop performance criteria – the aspects of social and economic impacts that will be the focus of the evaluation – e.g., improved NDT capacity and capability, increased scale and scope of NDT demand and use, etc.
3. Develop performance standards for each criterion – narratives that describe levels of performance such as 'excellent', 'good', 'adequate' and 'minor.
4. From the criteria and standards, select and identify the evidence needed and the methods that should be used to gather the evidence – e.g., surveys, case examples, administrative data, etc.
5. Gather evidence. Note that the evidence needed and means of gathering it need to be tailored to the circumstances of the project.
6. Analyse the evidence. At this stage, each evidence source is analysed separately, using methods suited to each source – e.g., quantitative analysis of survey data, qualitative analysis of case examples, economic analysis of costs and benefits.
7. Synthesise the evidence. At this stage, the streams of analysis are brought together to make evaluative judgements – ratings of performance according to the agreed criteria and standards.
8. Reporting, based on the criteria agreed in advance.

Following this sequence of steps helps ensure the evaluation is aligned with the RCA context, gathers and analyses the right evidence, interprets the evidence on an agreed basis and provides clear conclusions about the RCA's social and economic impact. Involving stakeholders in the design of the evaluation and the interpretation of findings supports understanding, ownership, validity and use (King, 2019).

The methodology was piloted in a case study of mutation breeding projects under the RCA (King, McKegg, Arau, Schiff, & Garcia Aisa, 2020) before being deployed in subsequent case studies.

Applying the methodology

Theory of change

A theory of change is a depiction of the programme to be evaluated, including the needs it is intended to meet and how it is intended to function (King, 2019). A theory of change "explains how activities are understood to produce a series of results that contribute to achieving the final intended impacts" (Rogers, 2014, p. 1).

The theory of change for the non-destructive testing programme (Figure 35) was developed iteratively by IAEA, selected experts from participating State parties, and the impact assessment team. Developing a theory of change in a participatory manner helps lead to a clear and shared understanding of the programme (Funnell & Rogers, 2011).

A theory of change may be used as a tool when assessing causality or contribution (Funnell & Rogers, 2011). In the case of non-destructive testing under the RCA, the focus was on the value added through regional collaboration. In the absence of a measurable counterfactual (e.g. a control group), the evaluation design theorised that regional

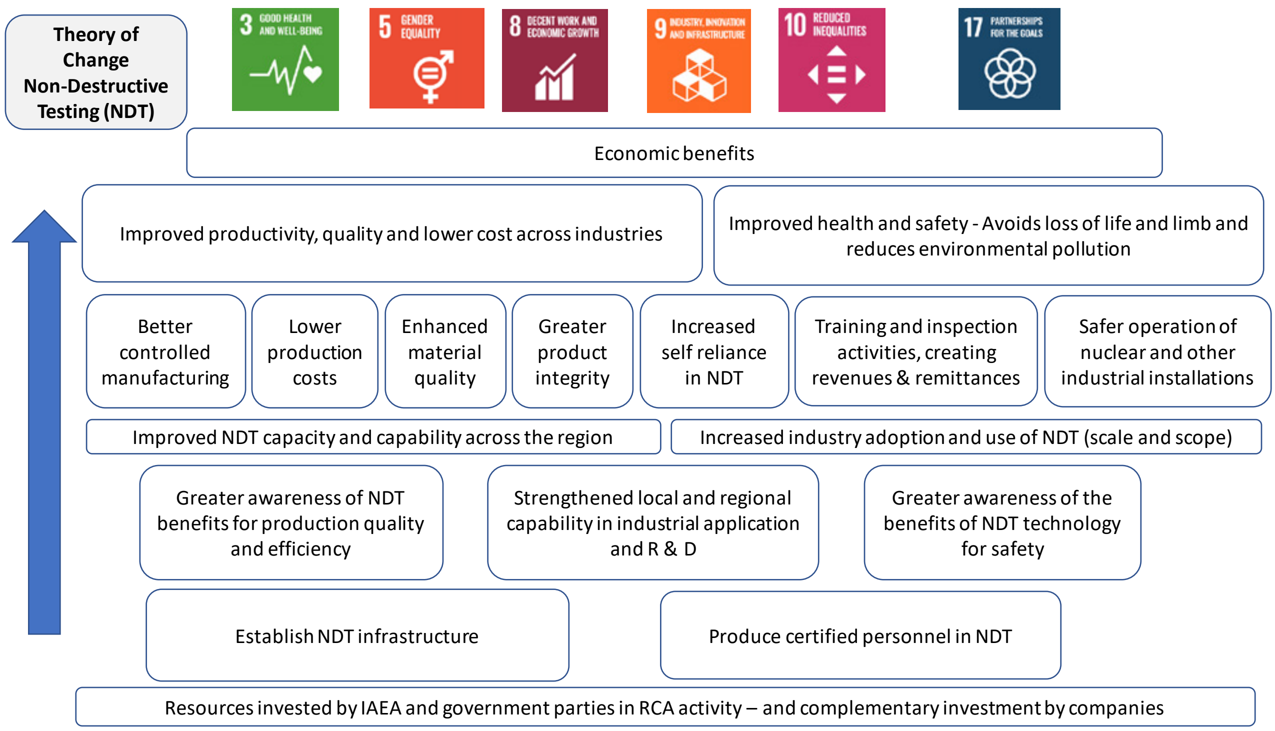


Figure 35: Theory of change for RCA non-destructive testing projects

collaboration would add value by enhancing, accelerating and expanding the development that would otherwise have happened. These theories were tested by eliciting feedback from the participating countries.

A theory of change can also be used to help identify a complete and coherent set of evaluation criteria (Davidson, 2005). For the non-destructive testing case study, it was agreed that the focus of the evaluation would be on four impact areas:

- Improved non-destructive testing capacity and capability
- Increased scope and scale of non-destructive testing demand and use
- Improved health and safety
- Economic impacts.

Criteria and standards

Evaluation criteria and standards for the four impact areas were collaboratively developed. Tables 9–12 set out the *rubrics* (criteria and standards) used in this impact assessment. Each rubric corresponds to a selected impact area from the theory of change.

Standard (to be applied to each State Party)	Criterion 1: Improved NDT capacity and capability
Excellent (exceeding expectations) State Parties with excellent status meet the standard for Good, plus:	State Parties have fulfilled the MRA requirements of ICNDT as a result of the support under the RCA. • NDT Society is registered with APFNDT and ICNDT • The society is a signatory to ICNDT MRA • NCB for NDT accredited to ISO 17024 • NCB accepted for registration under the ICNDT MRA • Accredited training centres offering ISO 9712 training. The support in establishing State Parties' NDT infrastructure through the RCA has enabled State Parties to produce *certified personnel in advanced techniques (RT-D, PAUT, TOFD, PEC, etc),* in addition to the conventional methods (RT, UT, MT, PT, ET). State Parties have achieved increased self-reliance in NDT, including offering training and inspection activities to local industries as well as abroad.
Good (meeting expectations) State Parties with good status meet the standard for Adequate, plus:	State Parties have established internationally-recognised NDT infrastructure at the national level as a result of the support under the RCA of IAEA. • NDT Society has been established • National certification body on NDT has been established. • Local NDT training centres are offering ISO 9712 training The support in establishing State Parties' NDT infrastructure through the RCA has enabled State Parties to produce certified personnel in all levels of NDTs' *five main methods* (RT, UT, MT, PT, ET) through the national NDT certification scheme.[20] State Parties have local NDT training centres and inspection companies offering services to local industry.
Adequate (meeting bottom-line expectations)	State Parties have established basic NDT infrastructure at the national level as a result of the support under the RCA. National certification scheme has been established and there are certified personnel produced by the national NDT certification scheme, however, for limited method(s) and not for all 5 main methods. There are trained personnel at the State Party organisation level. State Parties have training centres and inspection companies, owned by foreign entities.
Minor	The level of NDT infrastructure is below the standard for Adequate

Table 9: Rubric for criterion 1: improved NDT capacity and capability

20 Since most national certification schemes started late compared to other certification, acceptance is the main challenge.

Standard (to be applied to each State Party)	Criterion 2: Increased scope and scale of NDT demand and use
Excellent (exceeding expectations) State Parties with excellent status meet the standard for Good, plus:	From the involvement in the RCA, State Parties have managed to support the utilisation of the technology by industry and disseminate the knowledge developed through R&D by publishing research articles, organising international and national seminars and conferences. Participation in the RCA results in State Parties applying NDT technology in the industrial sectors for the QA and QC of industrial components – achieving better controlled manufacturing, lower production costs, ensuring material quality, and/or greater product integrity.
Good (meeting expectations) State Parties with good status meet the standard for Adequate, plus:	From the involvement in the RCA, State Parties have successfully applied the NDT technology to local industry, and established R&D activities. Participation in the RCA results in State Parties becoming more concerned and interested, and starting to apply NDT technology in the industrial sectors for the QA and QC of industrial components.
Adequate (meeting bottom-line expectations)	From the involvement in the RCA, State Parties have successfully managed to train personnel in the introduced technology. Participation in the RCA of IAEA results in State Parties initiating activities to create awareness among industrial organisations about the benefits of NDT technology for QA and QC.
Minor	Any of the standards for Adequate are not met.

Table 10: Rubric for criterion 2: increased scope and scale of NDT demand and use

Standard (to be applied to each State Parties)	Criterion 3: Improved health and safety
Excellent (exceeding expectations) State Parties with excellent status meet the standard for Good, plus:	As a result of participation in the RCA program of IAEA, State Parties have been applying NDT technology in the industrial sectors as set by countries' industrial laws for the QA and QC of industrial components – resulting in improved health and safety outcomes (i.e. fewer deaths and injuries) and/or reduced environmental pollution.
Good (meeting expectations) State Parties with good status meet the standard for Adequate, plus:	Participation in the RCA program of IAEA results in State Parties applying NDT technology for safer operation of nuclear and other industrial installations.
Adequate (meeting bottom-line expectations)	Participation in the RCA program of IAEA results in State Parties becoming more aware of the benefits of NDT technology for safer operation of nuclear and other industrial installations.
Minor	Standard for Adequate not met

Table 11: Rubric for criterion 3: improved health and safety

Standard (apply to State Parties collectively)	Criterion 4: Economic value
Excellent (exceeding expectations) Meets the standard for Good, plus:	Economic analysis suggests with a high level of certainty that the investment created more value than it consumed. Break-even is likely in nearly all scenarios (even under conservative assumptions).
Good (meeting expectations) Meets the standard for Adequate, plus:	Economic analysis suggests more likely than not, the investment created more value than it consumed. Break-even is likely in over half the range of scenarios (and under realistic mid-range assumptions)
Adequate (meeting bottom-line expectations)	Economic analysis suggests that under some scenarios, the investment created more value than it consumed. Break-even is possible (under plausible assumptions)
Minor	Break-even is unlikely (or only possible under optimistic assumptions)

Table 12: Rubric for criterion 4: economic value

Evidence for the assessment

The theory of change, criteria and standards provided important points of reference to identify what evidence is needed for the impact assessment. For this reason, selection of methods was undertaken after clarifying the theory of change, criteria and standards. This sequence of steps helps to ensure that the evidence is relevant and focuses on the right changes (King & OPM, 2018).

Examination of the rubric above revealed that the social and economic impacts of the RCA are diverse, and a mix of quantitative, qualitative and economic evidence was needed for the impact assessment. For example, economic value captured by firms providing NDT services has a monetary value that is relatively simple to estimate. However, benefits such as self-reliance in NDT, and health and safety improvements, are more difficult to value monetarily. Inclusion of additional methods and data sources enabled assessment of wider impacts and value shown in the theory of change.

Accordingly, the case study used a mix of methods, including:

- An online questionnaire deployed to all countries in the RCA
- Analysis of administrative data on non-destructive testing activity and costs, provided by IAEA
- Gathering additional information from non-destructive testing experts at the IAEA and State Parties
- Narrative case examples, written from details provided by selected countries on a selection of ‘success cases’ of non-destructive testing
- Economic analysis of costs and benefits of non-destructive testing projects under the RCA.

Online questionnaire

The online questionnaire was designed and piloted in May 2021 and deployed between June and August 2021. The data collection period coincided with the onset of the COVID-19 pandemic. The support and cooperation of country representatives and IAEA staff during these unusual circumstances is gratefully acknowledged.

The survey was structured in alignment with the rubrics to capture evidence needed in the four impact areas. It included a mix of quantitative (numeric or categorical) and qualitative (free-text) fields. The survey was administered electronically. Respondents entered data into a secure online form with automatic data validation. Responses were automatically compiled into a database for analysis.

Communication with countries about the online survey was led by the IAEA and included communication prior to deployment (to forewarn senior country representatives of the purpose and timing of the survey, giving them time to nominate a staff member responsible for completing the survey and set aside time for this task) and during deployment (including reminders, follow-up questions where needed to clarify responses and thanking country representatives for their close and effective cooperation). This communication and coordination from IAEA was critical to the success of the survey.

Case examples

Development of the case examples occurred following survey data collection. The selection of case examples was agreed with the IAEA. The senior contact person from each of the selected countries was contacted by IAEA to invite their participation.

Templates and instructions were developed for the countries preparing case examples and were sent to the nominated contact people. After receipt of the case study data, follow up contact was made with the contact people as required to clarify details. Narrative summaries were prepared.

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