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Nuclear Renaissance in Developing Countries: Challenges for the Introduction of a Nuclear Power Programme

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Affidavit

I, **Elisabeth Schneeweiß**, hereby declare

1. that I am the sole author of the present Master's Thesis, "Nuclear Renaissance in Developing Countries: Challenges for the Introduction of a Nuclear Power Programme", 127 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Abstract

Nuclear renaissance is a term coined to describe the introduction of nuclear power programmes in countries, mostly developing and emerging nations, that have not utilised nuclear power for energy generation up to now. In this study a framework for assessing the capabilities of these countries to introduce and sustain nuclear programmes has been developed: the Critical Powers Index. It consists of three separate indices of which the first one, the Preparedness Index, has been adapted from the International Atomic Energy Agency's Milestone Approach, which deals with legislative and regulatory issues. The other two indices, the Sustainability Index and the Emergency Preparedness Index, take into account factors pertaining to infrastructural and economic development as well as disasters preparedness and stability to allow a holistic analysis of a country's capabilities.

Representative for developed countries that already utilise nuclear power for energy generation, Japan has been chosen for evaluation. Sudan's analysis has been conducted as a proxy for all developing and emerging countries that are part of the global nuclear renaissance. Results show that less developed countries will be faced with considerable problems pertaining to their general development and are thus recommended to postpone the introduction of a nuclear power programme until these issues have been addressed. Furthermore, it has also become evident that sufficient emergency preparedness is a challenge even for affluent and developed countries like Japan.

The Critical Powers Index shows that the introduction of a nuclear power programme needs a holistic approach that not only takes issues directly related to the programme into consideration but also the general level of the country's development. It is thus recommended that the introductory period of 15 years is extended and the IAEA Milestone Approach reviewed and amended.

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List of abbreviations

ABWR	Advanced Boiling Water Reactor
AP	Additional Protocol
ASTOP	Asian Senior-level Talks on Non-proliferation
BWR	Boiling Water Reactor
CEPCO	Chugoku Electric Power Company
CHUBU	Chubu Electric Power Company
CSA	Comprehensive Safeguards Agreement
CTBTO	Comprehensive Nuclear-Test-Ban Treaty Organization Preparatory Commission
DRPEM	Department of Radiation Protection and Environmental Monitoring
EIA	Environmental Impact Assessment
FBR	Fast Breeder Reactor
FEPCO	Federation of Electric Power Companies
FNCA	Forum of Nuclear Cooperation in Asia
FNRBA	Forum of Nuclear Regulatory Bodies in Africa
GNEP	Global Nuclear Energy Partnership
GDP	Gross Domestic Product
GNI	Gross National Income
HDI	Human Development Index
HEPCO	Hokkaido Electric Power Company
HOKUDEN	Hokuriku Electric Power Company
HTGR	High-Temperature Gas-Cooled Reactor
HVDC	High-voltage direct current
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection

ICT	Information and communications technology
IDPs	Internally-displaced persons
IFRC	International Federation of Red Cross and Red Crescent Societies
IMF	International Monetary Fund
IsDB	Islamic Development Bank
JAEA	Japan Atomic Energy Agency
JAEC	Japan Atomic Energy Commission
JAERI	Japan Atomic Energy Research Institute
JAPC	Japan Atomic Power Company
JCFC	Japan Casting and Forging Corporation
JNC	Japanese Nuclear Cycle Development Institute
JNES	Japan Nuclear Energy Safety Organisation
JSW	Japan Steel Works
KEPCO	Kansai Electric Power Company
KYODEN	Kyushu Electric Power Company
LSBWR	Long Operating Cycle Simplified Boiling Water Rector
LWR	Light Water Reactor
MEM	Ministry of Energy and Mining
METI	Ministry of the Economy, Trade and Industry
MEXT	Ministry of Education, Sports, Science and Technology
MLIT	Ministry of Land, Infrastructure and Transport
MOE	Ministry of the Environment
MSv	Millisievert
NDT	Non-Destructive Testing
NEC	National Electricity Corporation of Sudan
NEI	Nuclear Energy Institute

NISA	Nuclear and Industrial Safety Agency
NRA	Nuclear Regulation Authority
NSC	Nuclear Safety Commission
NUMO	Nuclear Waste Management Organisation
OECD	Organisation for Economic Co-operation and Development
PWR	Pressurised Water Reactor
MOX	Mixed Oxide Fuel
MWe	Megawatt electrical
NEPIO	Nuclear Energy Programme Implementation Organisation
NNRR	National Nuclear and Radiological Regulator
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
RSI	Radiation Safety Institute
RPTC	Radiation Protection Technical Committee
SAEC	Sudan Atomic Energy Commission
SNRRA	Sudanese Nuclear & Radiological Regulatory Authority
SPEEDI	System for Prediction of Environment Emergency Dose Information
SRCS	Sudanese Red Crescent Society
SSAC	State System for Accounting and Control of Nuclear Material
SWU/yr	Separation work units per year
TEPCO	Tokyo Electric Power Company
TOHOKUDEN	Tohoku Electric Power Company
UN	United Nations
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organisation
YONDEN	Shikoku Electric Power Company

1. Introduction

The 21st century is characterised by a global strife for alternative and renewable energies to satisfy the ever-growing demand, which is no longer limited to the developed nations but largely driven by growth and advancement in emerging and developing countries. While renewable energies like solar, hydro and wind power are the focus nowadays, nuclear energy is another potential source of alternative energy to reduce dependence on fossil fuels.

This study discusses a phenomenon called "nuclear renaissance" which describes not the extension of already existing nuclear power programmes in developed countries but the plans of industrialising nations to implement such a programme on their soil. Two reasons can be cited as to why a developing or emerging country would invest in a domestic nuclear programme: the reduction of greenhouse gas emissions, as nuclear reactors are comparatively climate-friendly, and the relative ease with which a rapidly growing domestic energy demand can be met by nuclear energy. It is mostly the latter reason that prompts governments in developing and emerging countries to embark on a nuclear programme (Stulberg and Fuhrmann, 2013).

The aim of this study is to assess whether developing countries are capable of introducing and sustaining a nuclear power programme without having to rely to an unreasonable extent on foreign help. For this reason, the Critical Powers Index has been developed in chapter 2 of this study.

The Critical Powers Index consists of three separate indices, each further made up of several sub-indices. Its purpose is to take all issues a government will need to address to introduce its nuclear power programme in a safe and secure manner. The first index is the Preparedness Index, which is based on the Milestone Approach the International Atomic Energy Agency devised to help countries introduce nuclear power on their soil. As the issues addressed in this document are not sufficient to assess a country's capabilities to maintain the programme and deal with possible accidents, the Preparedness Index is complemented by two other indices. The Sustainability Index, which deals with issues concerning the level of development the country concerned, depicts infrastructural and educational issues as well. The third index being part of the Critical Powers Index, the Emergency Preparedness Index, assesses a country's stability, together with its capabilities to deal with general disasters as well as the monitoring of and protection from radiological accidents.

In chapter 3 the Critical Powers Index is applied to two countries, Japan and Sudan. The research question of this study can be thus formulated as: *Are Japan and Sudan, using the Critical Powers Index for assessment, capable of introducing and sustaining a domestic nuclear power programme?*

Japan, a country with a long history with nuclear power, stands representative for developed countries with an already existing nuclear programme and thus its analysis shows the direction a developing country like Sudan should take, while also highlighting difficulties and deficiencies even a country as highly developed as Japan is faced with. Sudan, on the other hand, stands representative for all the developing and emerging countries that plan on being part of the global nuclear renaissance, and the problems that will be identified in the course of chapter 3's analysis will be problems that those other countries are faced with as well.

Chapter 4 of this study then evaluates the analysis's results to identify the main differences between Japan and Sudan. This evaluation will then be used to make a recommendation for the review and amendment of the IAEA Milestone Approach, as the Critical Powers Index shows that many issues that need to be taken into account for the safe and secure introduction and maintenance of a nuclear power programme have not been given sufficient consideration yet. The study eventually closes with concluding remarks in chapter 5.

Literature on the topic of introducing a nuclear power programme is scarce. The main piece of literature dealing with these issues is the "Milestones in the Development of a National Infrastructure for Nuclear Power" the IAEA released to support those governments that have concrete plans to introduce nuclear power programmes. This document is complemented by other official IAEA publications on issues dealing with nuclear power. Apart from those, no other books or articles deal with the overarching set of issues that have to been dealt with when embarking on a nuclear journey. As for the nuclear programmes of the countries analysed in this study, it can be said that literature on Japan's nuclear programme and all legal and regulatory considerations are manifold. The most important document on Japan is titled "Nuclear Legislation in OECD and NEA Countries – Japan" (Organisation for Economic Co-operation and Development, 2011) and deals with all regulatory and legislative issues on the country's nuclear power programme. In addition, an article of the World Nuclear Association gives an overview of the development and current state of Japan's nuclear programme and industry (World Nuclear Association, 2014a). In contrast, information on Sudan's nuclear power programme is only scarcely available, which mainly results from the fact that the Sudanese government has only recently expressed interest in the topic. Thus, there is no overarching document on the country's nuclear programme, which means that information had to be collected from several articles and presentations.

The purpose of this study is to develop a new framework to assess a country's capabilities to introduce and sustain a nuclear power programme for which the Critical Powers Index is being developed and subsequently tested on Japan and Sudan. It aims to help promote a safe and secure utilisation of ionising radiation to generate energy and to raise public confidence and support as nuclear power can be an important alternative to fossil fuels in the future.

2. Critical Powers Index

2.1 General

In this chapter I will present the Critical Powers Index, which will be used in the following part of the study to access if Japan and Sudan are prepared for the introduction of a nuclear power programme in their country. Japan, which already has a functioning nuclear programme, will be used as a model country to examine the sufficiency of the Critical Powers Index, while Sudan will be used as one of the countries that actually want to implement nuclear power within the next decades and thus need to be ready to implement their plans. The Index is made up of three sub-indices, the Preparedness Index, the Sustainability Index, and the Emergency Preparedness. All three sub-indices will now be outlined, and at the end of the chapter the overall score of the Critical Powers Index will presented (including weighting factors), and a minimum score that should be reached by a country wishing to introduce nuclear power will be elaborated.

2.2 Preparedness Index

2.2.1 The Milestone Approach

The International Atomic Energy Agency (IAEA), established in 1957 as an independent organisation by the United Nations, states in Article II of its Statute that it "*shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose*" (International Atomic Energy Agency, 2014a). Among its object is thus the promotion and implementation of nuclear energy and techniques utilising ionising radiation for peaceful purposes in fields including, but not limited to water desalination, food security, health care and environmental management in order to facilitate sustainable development across the globe (International Atomic Energy Agency, 2013a).

Despite ongoing concerns about nuclear proliferation and the possibility that radioactive material gets abstracted and made into radiological dispersal devices, for which a tight safeguards regime has been set up under the surveillance of the IAEA and the

Comprehensive Nuclear-Test-Ban Treaty Organization Preparatory Commission (CTBTO), any country in the world will find the support of the international community for their endeavour to introduce nuclear power programmes. The only preconditions are that the country concerned joins the international Nuclear Safety Regime and pledges its commitment to the usage for nuclear power for peaceful purposes only (ibid.).

One of the main reasons for a state to join the ranks of countries utilising nuclear power is to meet the growing energy demand of its population and industry, which in the last decades saw a dramatic increase especially in developing countries. Calculations predict that global energy demand will grow by fifty percent until 2030, of which more than two thirds will be caused by increases in consumption in the developing world. For those countries this either means to rely on fossil fuel imports to a higher extent than already is the case at the moment and thus further increase their dependence on outside powers – not including those countries that have such reserves on their territory – or investing in alternative energies, both green energies as well as nuclear power (International Atomic Energy Agency, 2007).

Development is closely linked to production of energy and the access to it. With the promotion of nuclear power as an alternative to fossil fuels, the International Atomic Energy Agency fosters the development and reduction of poverty, while the transfer of science and technology furthermore aims to stimulate a rise in educational levels and industrial capabilities. However, countries that want to introduce their first nuclear power plant are faced with a variety of challenges, with the extent of the difficulties increasing the less developed the state concerned is. To help potential candidates for nuclear power plants realise their project in a safe and sustainable manner, the IAEA offers support in all fields of concern in form of informational publications, workshops, and technical assistance for a successful implementation of nuclear power. One of these publications is the "Milestones in the Development of a National Infrastructure for Nuclear Power" (International Atomic Energy Agency, 2012).

This document, often abbreviated as Milestone Approach, deals with all the challenges for the country's infrastructure that need to be taken into consideration when planning to implement nuclear power. A brochure with the title "Considerations to Launch a Nuclear Power Programme" was published in 2007, giving an overview of the issues presented in the Milestone Approach later in the same year. Its object is to "*facilitate the assessment of progress towards the development of infrastructure for a country that is considering the introduction of nuclear power as part of its national energy strategy*" (International Atomic Energy Agency, 2007).

For this the IAEA divides the whole period beginning with the first firm decision to invest in one's own nuclear power plant until the eventual start of its operation into three distinct phases. In each phase a total of nineteen different infrastructural issues will have to be addressed. Only by complying with each of these criteria a country can reach one of three milestones and advance to the next phase. These three milestones are "Ready to make a knowledgeable commitment to a nuclear programme", "Ready to invite bids for the first nuclear power plant", and "Ready to commission and operate the first nuclear power plant" (International Atomic Energy Agency, 2014b).

The authors of the Milestone Approach do not claim that the document is comprehensive in taking into consideration all possible infrastructure issues that need to be addressed when deciding to embark on a nuclear journey. It simply tries to help a country assess in which areas of infrastructure, including both legal and regulatory considerations ("soft" infrastructure") as well as grid expansion and nuclear facilities ("hard" infrastructure), improvements and amendments need to be addressed in order to implement nuclear power in a safe and secure manner (International Atomic Energy Agency, 2007).

When analysing the Milestone Approach, two things can be noticed: First, that the legal and regulatory considerations take a prominent role in all nineteen issues, as the focus lies on implementing laws that appoint responsibilities to the government, regulatory bodies, or the operator. The second distinctive feature of the document is that the issues taken into consideration for reaching each milestone only concern the infrastructure directly related to the nuclear power plant, i.e. the plant itself, as well as facilities for interim and long-term storage and waste management. The general state of the infrastructure of the country concerned is not questioned, meaning that shortcomings on that level are not taken into consideration as the document does argue that a certain basic level of economic development should be a precondition to sustain the programme with expertise, technologies and various components that will be needed.

It is because of this reason that the Preparedness Index, which covers the main points of the Milestone Approach, is only one part of the Critical Powers Index used for my analysis of whether a country is capable of building and sustaining a nuclear power plant. Legal and regulatory considerations as well as issues concerning the management of the nuclear power plant are an important part for the introduction of nuclear power in a country. To successfully operate and sustain a project like this for at least one hundred years including decommissioning of the plant and waste disposal (International Atomic Energy Agency, 2007), many more issues, in parts more basic ones yet of even higher importance, have to be taken into consideration. These will be discussed in the other two indices.

For my analysis, I allot a total of one hundred points to the Preparedness Index, the base sum for each of the three indices presented in this section. I have decided on four main categories, each given 25 points that can be potentially reached by the country in question, that make up the Preparedness Index: Laws concerning a nuclear power programmes, regulatory considerations, site selection issues, and management issues. These four categories sum up the nineteen issues presented in the Milestone Approach, and thus are used as a representative for it in this study.

2.2.2 Laws concerning a nuclear power programme (25p)

When embarking on the plan to introduce nuclear power in its country, the government is confronted with the task of having to adapt its legal framework in order to operate in a safe and secure environment. Both on the national level as well as on the international scale adjustments have to be carried out. The government's goal has to be the development of an overarching legal framework with a comprehensive coverage of the aspects of nuclear law, including security and safety concerns, commercial issues as well as a clear assignment of nuclear liability. Only with the introduction of these laws and regulations the development of programmes for the implementation of measures concerning environmental protection, emergency planning, safeguards and the like becomes possible (International Atomic Energy Agency, 2007).

The ultimate goal is to have a national infrastructure that deals with all issues concerning nuclear power like radiation, transport safety and waste disposal, for which the application of international standards is absolutely vital and needs to cover all facilities, practises and activities. Nevertheless, the implementation and revision of the national law lies ultimately with the country's government, meaning it should address that task according to its political and legal traditions and cultural values (International Atomic Energy Agency, 2007).

There are seven main fields of national law that need addressing immediately after deciding to embark on a nuclear programmes to ensure that all legal and regulatory uncertainties are cleared up by the time the operation of the plant should begin: First of all, adaptations and revisions to the current national energy policy have to be made in case nuclear power is not included in it. In this context, questions about the institutions responsible for the enforcement of the nuclear programme have to be answered and the relationship with the government clarified. Furthermore, the role of the national as well as local government has to be codified in legislation; the same applies for the stakeholders, including the operator and public. Next to these basic considerations, legislation dealing with all issue areas of nuclear power has to be considered. Laws concerning licensing as well as inspection and enforcement have to be implemented together with those dealing with spent fuel and radioactive waste, spent fuel, safeguards, import and export controls, environmental and radiation protection as well as laws assigning liability and coverage. A further important legal element is the control and surveillance of the whole nuclear fuel cycle, which will need a whole new set of laws and provisions, including an answer to the question who owns the nuclear material. Foreign investment laws, including property rights and the role of foreign entities will also need to be checked for necessary amendments. While not directly related to nuclear law, legal adaptions to the education system and curriculum should be implemented as well to ensure the capability of the country's population to sustain the nuclear power programme in the future (International Atomic Energy Agency, 2007).

The list of legislative revisions and amendments that need to be considered is long and can pose a challenge to a country with a new nuclear programme. However, these are only the laws on the national scale that need to be in place before reaching the third milestone. Of the same importance are the international treaties and policies that have to be signed in order to join the global nuclear safety regime to get the IAEA's support for the programme. The first step for the country in question is to avow its commitment to the use of nuclear power for peaceful purposes only – both in national as well as international legislation (International Atomic Energy Agency, 2007).

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) was adopted in 1968 by the United Nations and came into force in 1970. Its object is to support the use of nuclear power for peaceful purposes while trying to prevent the spread and mishandling of nuclear materials and weapons technology. In the NPT a safeguards system has been established. While the International Atomic Energy Agency is not a party to the treaty, it is entrusted with the task of administering these safeguards and supervising its members' adherence to them (International Atomic Energy Agency, 2014c; 2014d).

Today 178 sovereign states are parties to the treaty and have conducted further safety agreements with the IAEA. These usually exist in the form of so-called Comprehensive Safeguards Agreements (CSA) for non-nuclear weapon states, which often also signed an Additional Protocol (AP) for implementing strengthened safeguards. The object of these protocols is the verification of the signatory country's commitment by means of progress reports or inspections, as laid out in Article XII of the IAEA Statute. Countries that want to embark on a nuclear programme are also obligated to establish a State System for Accounting and Control of Nuclear Material (SSAC), which is set with the task of ensuring the implementation and application of the necessary safeguards (International Atomic Energy Agency, 2007; 2104a; 2014e).

Next to these agreements surrounding the Non-Proliferation Treaty, further international instruments have to be taken into account by governments that want to introduce nuclear power in their country. Examples are the Convention on Early Notification of a Nuclear Accident, the Convention on Physical Protection of Nuclear Material, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, or the Convention on Supplementary Compensation for Nuclear Damage. All these treaties and provisions serve the goal to build a global and uniform safety system where all its members apply the same quality standards regardless of their level of development. If a country wants to operate a nuclear power plant, it has to follow these rules, even though help from the IAEA to reach accordance with them can and will be provided (International Atomic Energy Agency, 2013a).

Having a comprehensive framework of both national as well as international laws in place will reward the countries of my analysis a maximum of 25 points. The main focus will be on the most important international treaty, the NPT, as well as the national legislation to address the question of responsibilities and other issue areas of nuclear law. A minimum of 15 points should be reached even if the country is only in the first phase of the Milestone Approach, as it is vital to clarify any legal questions before advancing the project further to ensure a safe and secure implementation of the project.

2.2.3 Regulatory authorities (25p)

Together with the legal considerations that have to be taken, the establishment and implementation of regulatory authorities is vital for the introduction of nuclear power in a country. To oversee the nuclear power programme implementation plan as well as the development and introduction of the reactors, the IAEA advises the establishment of a Nuclear Energy Programme Implementing Organisation, short NEPIO. This organisation should be independent and have a variety of authorities to not only cooperate with other national agencies, but also conduct international negotiations and cooperation. Its main function, however, is the establishment of an autonomous regulatory body (International Atomic Energy Agency, 2007).

NEPIO is involved in all other infrastructure issues presented in the Milestone Approach. Especially in Phase 1 it needs to deal with a lot of tasks, starting with the conduction of a comprehensive study of the issues that need to be tackled. Furthermore, the core regulatory functions have to be assigned concerning review and assessment, public information, licensing and enforcement. In the second phase, when the legal framework should be implemented already, the NEPIO will need to get in close contact with the future operator or owner organisation. In general, all regulatory issues concerning safeguards, nuclear material, its transportation and storage, and further standards for siting and construction need to be addressed by the members of the regulatory authority in Phase 2 (IAEA, 2007).

Having an independent regulatory organisation to oversee the implementation of the new legislative framework is one of the most important both in the Milestone Approach as well as for the Preparedness Index of this study. Only by the establishment of such a body the safe and secure introduction of a nuclear power plant can be guaranteed. Similar to the former category, this one has a maximum of 25 points, 15 of which can be reached if the government of the country concerned has already designated such an authority. To gain even more points, it is of importance that the regulatory body is equipped with a broad variety of authorities and shows the necessary transparency so that its work and decision can be evaluated.

2.2.4 Site selection (25p)

The site selection process is of utmost importance when planning to build a nuclear power plant both in countries new to the technology as well as in those that already use a nuclear programme for peaceful processes. The aim of a careful site selection is to guarantee the highest safety possible while keeping potential impacts on environment and population to an absolute minimum. This is also true for all supporting facilities including interim and long-term storage sites for spent fuel and radioactive waste.

There are four main factors that should be taken into account for site selection. The first is technical feasibility, which includes questions concerning the workload of land formation, the power grid, the availability of water for cooling and other purposes, as well as existing transport routes and the proximity to industrial centres. In close relation to this stands the second factor, the economic rationality, in which costs for water, transport, transmission, and engineering are taken into account. While safety should be the main concern for site selection, economic rationality is nevertheless important for financing the plant. Introducing nuclear power and maintaining it demands significant expenditures, which might force developing countries to ask for financial aid even if they manage to find the most cost-effective site. The third and fourth factors important for site selection are the safety and security of the site, as well as characteristics corresponding to environmental compatibility. It is these two factors that are of essential importance in the section for site selection and evaluation of the Milestone Approach to ensure that the area in which the nuclear power plant is to be built is safe in terms of geology, seismology, and other environmental effects and man-made events (Wu, Narenmandula, and Han, 2012).

For this reason site surveys need to be conducted early in the first phase already, usually commissioned by the NEPIO. Potential sites need to be characterised, selected and secured in time to ensure that they are available in case they are chosen, Another important factor concerning site selection is the involvement of the public and other stakeholders, that will need to be sufficiently informed and educated to gain their support and approval for the site (International Atomic Energy Agency, 2007).

As with the other categories of this index, site selection will have a maximum of 25 points. For this analysis, I will look at how far the candidate countries are with their surveys and whether they have already picked (a) potential site(s). Should a site that is deemed viable by all parties involved as it confirms to all necessary criteria have already been selected, it would net the country the maximum points for this category. Should site selection surveys be conducted at the moment, or if a list of potential sites has already been complied, 15 points will be awarded. If, however, either no studies on sites have been commissioned or a site is being considered that does not fulfil the safety requirements only five points will be rewarded.

2.2.5 Management issues (25p)

Management of a nuclear power programme is a demanding task for which a highly competent team is needed. Furthermore, the responsibilities and roles change as the introduction progresses. In the beginning, the NEPIO is tasked with general management of the nuclear power plant programme and the evaluation of siting studies, financing and other issues. Already in the first phase of the Milestone Approach the question regarding the ownership of the plan as well as responsibilities regarding its operation have to be addressed. The designated operator organisation will then be tasked with a variety of functions by the start of Phase II as the construction of the plant is being prepared (International Atomic Energy Agency, 2007).

The IAEA recommends that the operator/owner organisation addresses issues concerning the formal management system of the future plant, including staffing and the training of employees, as well as the implementation of regulations concerning safety and security, financing and technologies used on site and for waste management. While the role of the designated regulatory authorities lies with the implementation of laws and regulations, and the communication with stakeholders and the international community, the owner/operator is task with the management of issues concerning the introduction of the nuclear power plant itself (ibid.).

Apart from considerations about safeguards and security protection, a main issue that has to be addressed by the management authorities is the fuel cycle. An elaborate plan encompassing the whole fuel cycle should be developed already in the early stages of planning. It needs to clarify both the front end of the cycle as well as the back end, meaning both the acquisition of nuclear fuel including enrichment and fabrication, as well as interim storage of spent fuel, its transportation to treatment or reprocessing plants and its eventual disposal. For this reason, the decision on which type of reactor will be built should already be taken in the early phases of the nuclear programme, so that contracts for the supply and service of necessary fuel cycle components can be concluded on time (ibid.).

As the fourth subcategory of the Preparedness Index, Commercial Management will also be allotted 25 points. It is vital that the country in question decides early on who will be the operator/owner of the future nuclear power plant and what type of reactor will be built, which will be the precondition to reach the minimum of 15 points in this category. Only if these issues are clarified, questions concerning the nuclear fuel cycle can be addressed. If the country concerned has already developed a fuel cycle strategy it will be awarded with 20 points. 25 points can only be reached if issues concerning the back end have already been tackled, because while long-term storage facilities will not be needed immediately when operation starts, they pose a big challenge for all countries with nuclear facilities.

2.3. Sustainability Index

2.3.1 General

The aim of the Sustainability Index is to assess whether a country is able to sustain a nuclear power plant during its operation with little to no outside help. To achieve this goal, the country in question needs to have reached a certain level of development and have basic infrastructure in place because, while all services can be acquired in form of turn-key nuclear power plants from companies like Areva and the international community, excessive dependence on outside support not only puts a financial strain on the country, but could also prove as a liability when a timely response to an unforeseen event is needed. To assess the country's capabilities in regard to these issues, the Sustainability Index was developed.

2.3.2 Gross Domestic Product and the Human Development Index (10p)

To assess the general development of a country, a variety of factors are used by scientists and governments alike. One of them is the Gross Domestic Product, abbreviated as GDP, which is often cited to be a "*reference point for the health of national and global economics*" (Callen, 2012). It is used because it gives an overall picture of the economy, its size and whether it is growing or contracting, thus being used as an indicator of the well-being of a country's population. On a per capita basis the GDP is often considered to reflect the country's living-standard, as it shows the pace with which the income grows per capita (United Nations, 2007).

Another index for measuring the general development is the Human Development Index (HDI), which is has been published by the United Nations Development Programme (UNDP) since 1990. It was first developed by Amartya Sen, an Indian economist, together with Mahbub ul Haq, an economist from Pakistan. Since 2010 it is calculated using three different measurements: Education, life expectancy, and income (Gross National Income [GNI] per capita). These three combined, you get a value between 0 (low development) and 1 (very high development), which is then divided into four categories: very high development (0.800-1), high development (0.711-0.799), medium development (0.535-0.710), and low development (less than 0.535) (United Nations Development Programme, 2013).

These two measurement factors have been chosen as they give an overview not only of the development of a country, but also the capability of it to sustain a nuclear power plant. Economic performance, as reflected both in the GDP (per capita) of a country as well as its GNI, is a good indicator to assess the level of development of the country discussed. As will become apparent in the next subcategories of the Sustainability Index, it is vital for a country to possess the capabilities to sustain the nuclear power plant on its own without unnecessary dependence on other countries and foreign companies. Thus the economic performance including the financial situation of a country together with the education of its population can be used as a general indicator for its capability to sustain a nuclear power programme.

The maximum points for this category are ten points, which would be allotted if the country in question has a very high HDI (six points) as well as high GDP per capita (four point), whereas a low HDI would only net a country 1.5 points, and a low GDP per capita only one.

2.3.3 Economic development and quality of infrastructure (30p)

Economic development is made up of the policies and processes a government employs to improve the political and economic situation of a country and its people's social well-being, and thus works to improve the factors described in chapter 2.3.2. Three main areas are encompassed by economic development: Policies to promote economic objects such as monetary and fiscal policies to raise employment and foster economic growth; policies for job creation and retention; and programmes to develop and strengthen infrastructure and services (Salmon Valley Business & Innovation Center, 2011).

Infrastructure deficits are pervasive in developing countries and are believed to be one of the main reasons for poor growth prospects. It is thus crucial to increase spending in new projects and also to improve already existing infrastructure to not only alleviate growth constraints but to face the challenges of a growing and developing population as well (Bhattacharya, Romani and Stern, 2012).

A good economic development together with a functioning infrastructure which meets the basic demands of the country's people is vital for sustaining a nuclear power programme. A functioning public infrastructure is absolutely necessary for the construction and operation of the plant as well as in case of emergency when evacuation could be necessary. Furthermore, the partitioning of the economy in its different sectors also gives an overview of the educational development and the country's capability to sustain their nuclear power plant. Especially the development of the manufacturing and service sectors are of interest for a nuclear programme (ibid.).

When talking about infrastructure, governments and scientists usually mean the sum of electricity, telecommunication, transport, as well as water supply and sanitation/sewage. For nuclear power it is the former few categories that are of importance if one wants to build and sustain a power plant (Estache and Garsous, 2012). The national electrical grid is a key component for the introduction of nuclear power in a country. Its main role is to get the electricity produced from the power plant to the population. Access to electricity has a strong impact on the development of a nation, and ever-rising demand of it is one important reason to invest in nuclear power. It has been shown that investments in the electrical infrastructure achieve "*high social rates of return*" (Estache and Garsous, 2012).

Nuclear power plants are best used for base load generations, even though one plant alone should not generate more than five to ten percent of the installed capacity, as this could produce a critical shortage of electricity if it has to be shut down. Because of its high energy output, it is important that the electricity grid is big and stable enough to allow most, if not all the energy generated by the nuclear power plant to be fed in. Furthermore, a stable grid is also vital for emergency situations in which external supply of power might be necessary (International Atomic Energy Agency, 2007).

Several factors impact the interaction between grid and power plant: the location of the plant in relation to the grid because of transmission losses and necessary extensions of the grid; the plant size and its compatibility with the grid; and the reliability of transmission lines and interconnections (International Atomic Energy Agency, 2006). If all these factors have been accounted for and the general shape of the electricity grid is adequate, the country in question would get the maximum of ten points for this subsection of infrastructure. However, if a sizable proportion of the population has no access to electricity and the other experiences frequent power outages, only two points will be allotted.

Similar considerations have to be made for transportation infrastructure. Roads, railways and, if applicable, ports are of central importance for the introduction of nuclear power in a country. A fully developed transportation infrastructure is needed make travel within a state and the interaction with its neighbours possible, which helps alleviate differences in regional development and catch up with other, more developed countries (Estache and Garsous, 2012). For a nuclear power programme the size and quality of transportation infrastructure is already important for the construction of the plant. While purchases of a turn-key power plant are possible nowadays, access to the site nevertheless has to be provided by the country in question. This includes roads that can withstand the weight of heavy machinery and vehicles loaded with heavy components. Furthermore, a fully developed transportation infrastructure is also needed for handling and transporting nuclear waste across the country and abroad. Land-locked countries without direct access to harbours and ports are at a disadvantage in this regard. If they wish to send their spent fuel abroad for treatment and reprocessing, they will have to discuss passage with their neighbours and other countries that might be needed to ship and eventually return their radioactive waste (International Atomic Energy Agency, 2006).

If a country has a good transportation infrastructure in place, which includes roads, railways and port sites that are capable of supporting the construction of the nuclear plant as well as the handling of waste material and spent fuel, it would be awarded the maximum of ten points. If the state of the transportation infrastructure is good, yet no access to ports is given, this would result net the country only eight points. If, however, the transportation infrastructure is in a very bad shape, with roads and railways being in a bad condition, if existent at all, the country in question would only be allotted two points.

This category as a whole has a maximum of thirty points, Using the Quality of Infrastructure Index of the World Economic Forum's Global Competitiveness Report from 2011[1], a good shape of the general infrastructure and promising economic development would net a country ten points, whereas a value of less than the mean would net the country only five points.

2.3.4 Industrial development (20p)

Industrial development is not only a vital factor in providing employment for a country's people and thus poverty reduction and general development; it is also needed

[1] See: World Economic Forum (2011): The Global Competitiveness Report 2011-2012. World Economic Forum. [Online] http://www3.weforum.org/docs/WEF_GCR_Report_2011-12.pdf - accessed: May 5, 2014.

for sustaining a nuclear power plant. To do so it is of importance that a country can provide the key-elements of nuclear technology themselves. However, the vast majority of countries currently striving to introduce nuclear power possess only low industrial capacities and thus will need to depend on imports from international suppliers for all services and components, especially spare parts and nuclear material (Kroenig, 2013). This is not only inconvenient but also cost-intensive, which is why a government should invest in introducing technologies and supporting industries that are capable in establishing a local nuclear industry. This is also a unique opportunity to foster national industrial involvement and create economic growth and jobs for the country as a whole. To achieve this, national capabilities need to be assessed already early on so that industrial and business leaders can be consulted and programmes and plans to enhance skills of the workforce can be assessed and improved. It is important to adhere to international quality standards, which might prove to be a problem for less developed countries, though (International Atomic Energy Agency, 2007).

If a country has an industrial base sufficiently developed to easily adapt to producing components for nuclear power plants, it would be awarded with the maximum of twenty points for this category. If this is not yet the case but plans are already being devised to ensure self-sufficiency in the near future, it will still get 15 points. An industrial development that has seen fast growth in the last years will award it with ten points, while low one will only get it five points.

2.3.5 Financing (20p)

Introducing a nuclear power programme with all its necessary developments and components is a long-term endeavour with large financing requirements. The country wanting to build a nuclear power plant needs to think not only of the expenses covering the construction of the plant itself, but also the costs for infrastructure development and the different studies that need to be conducted, but also the costs of maintenance and eventual decommissioning. Furthermore, waste management is also a costly factor that needs to be taken into consideration. Because of this high financial expenditure, most nuclear power projects are financed in part by equity and debt financing (Organisation for Economic Co-operation and Development, 2009).

The costs for constructing a nuclear power plant of the third generation will usually amount to around USD 5-6 billion in countries that are members of the Organisation for Economic Co-operation and Development (OECD), while this sum might be even higher in developing countries. In this calculation the expenditures for waste management and eventual decommissioning are already included. Only very well-capitalised and large utilities would be able to finance such a project by themselves. For state-owned enterprises in developing countries this is an even bigger challenge (Nuclear Energy Agency, 2012).

Long-term financial security to guarantee a safe operation and eventual decommissioning of the plant is of essential importance if a country wants to introduce nuclear power, as a nuclear accident will mean an even harsher financial burden that might prove too much for the country to shoulder. Thus I will look at the general financial situation of the country, how it plans on financing its nuclear power programme, and what measures it means to implement to ensure the financial coverage in the future and in case of emergency. If the country is able to finance its plant construction without monetary aid and is judged to be in such a situation as to be able to financially cope with accidents, it will be awarded the maximum of twenty points. If, however, the budget situation is very difficult and the plant is financed by foreign debt or aid only, the country will only be allotted five points.

2.3.6 Human resource development and education (20p)

Human capital is not only an important driver of economic growth (Hanushek, 2013), a well-educated population is also vital for the sustaining of a nuclear power project. To ensure a safe and secure operation of a nuclear power plant during its life time of forty to sixty years, it would be of great advantage to assign the management and control functions to staff from the country itself to make use of job positions being generated by the introduction of nuclear energy. To achieve this goal, two conditions have to be met: On one hand the general education of the population needs to be secured, on the other hand programmes in university as well as special training courses need to be established to convey knowledge about nuclear energy and technology to the future staff.

To reduce poverty and generate economic growth it is necessary to not only implement mandatory primary education for the people, but to increasingly boost secondary education as well. Only then the chances of bringing large shares of the population out of poverty are high. However, the quality of the education including what subjects are being taught to the children is also of importance to achieve this goal (International Institute for Applied Systems Analysis, 2008; Epstein and Yuthas, 2012).

In addition to the general level of education in a country, university degrees with focus on nuclear science as well as engineering and technology are important to ensure self-sufficiency in staffing without relying too much on outside personnel. However, as only few countries will be capable right away to acquire the technological knowledge to impart on their population, training programmes in cooperation with the IAEA and other countries will also be looked at in this subcategory. Because, as was the case with South Korea, an initial import of qualified manpower in combination with educational programmes in collaboration with the United States and the IAEA ensured the eventual independence from outside help (Choi et al., 2009).

If the analysis shows that the country in question has a comprehensive educational system with enough universities offering degrees in nuclear and natural sciences, it will be awarded with the maximum of twenty points for this category. If general education is implemented while for specialised training outside help is being sought, it will get 15 points. For deficits in education where a sizable part of the population only received primary education or is illiterate, ten points will be awarded, while for even lower educational standards only five points will be given.

2.4 Emergency Preparedness Index

2.4.1 General

The final index that is part of the Critical Powers Index deals with emergency planning and preparedness. While the probability of a severe accident is claimed to be between one in 10,000 reactor-years of experience for old plants and up to one incident with core-damage in 1.6 million years for new reactors, emergency preparedness is nevertheless a central factor when planning to introduce nuclear power in a country, because if something goes wrong it can have devastating consequences for the people and the environment (Ramana, 2011). Furthermore, emergency preparedness also includes smaller events as leakages or light contamination of workers for which the government and plant owners also need to be prepared. Similar to the other indices, this one has a total of one hundred points and is made up of four subcategories à 25 points.

2.4.2 Political stability (25p)

Political stability describes the "*legitimacy, continuity, and effectiveness of the constitutional institutions and the possibility of removing unpopular governments by a multi-level construct*" (Widmaier, 1990). This includes the separation of power, which is of special importance for the introduction of nuclear power as the possibility of objection to these plans and the independence of the regulatory authority should be guaranteed. Furthermore, political stability is also often defined as "*the absence of civil wars, of coups (successful or attempted), of frequent constitutional changes (for example, a change from dictatorship to democracy), and of domestic political terrorism, corruption, and expropriation*" (Posner, 1997). Failed states are usually characterised by having lost the ability to perform their basic function, the erosion of authority, including the inability to control (part of) its territory (Global Policy Forum, 2014).

A stable political situation and the complete control of the country's territory are of central importance when trying to implement a nuclear power project to ensure the continuing safety and security of the plant. Plant safety and the safe transport of radioactive material and spent fuel have to be guaranteed. If a country is considered stable enough and has a low probability of terrorist attacks, it will be awarded the maximum of 25 points. The less stable the country is, the fewer points it will be rewarded. If it is considered to be a failed state with a high possibility of attacks by paramilitary groups and terrorists, no points will be allotted.

2.4.3 Medical infrastructure (25p)

A comprehensive health care system, whether provided by the government or private entities, is essential for economic development and the social well-being of the population; but for the maintenance of a nuclear power programme a functioning medical infrastructure is also of special importance. An assessment of health care systems includes the following factors: effectiveness, which describes the access to care and its quality; equity, describing the accessibility for disadvantaged groups without means to finance treatment; and efficiency, including administrational quality and cost-effectiveness (Kruk and Freedman, 2007).

A functioning health care system will be needed for disaster relieve and in case of a nuclear accident for which the protection and treatment of contaminated workers and the general populace is of special importance. For that reason I will look at the overall state of the country's medical infrastructure and its equipment for dealing with radiation release. Should it be judged sufficient enough to deal with such challenges, the country discussed will be awarded 25 points. If the health infrastructure shows deficiencies in that regard, only 15 points will be allotted. In case the medical infrastructure is hardly developed, only five points will be given.

2.4.4 Disaster management (25p)

Disaster management describes the creation of a network for communities to reduce the vulnerability to disasters and hazards and the ability to cope with such events. The goal is to foster communities that are less vulnerable to such disasters for which a comprehensive, integrated, coordinated as well as flexible emergency planning is necessary (Maine Emergency Management Agency, 2008).

Disaster management can be described as a cycle: "*prevention, mitigation, preparedness, response and recovery*" (Mishra, 2002). It considers both natural disasters like earthquakes as well as man-made ones like industrial accidents. A comprehensive strategy to cope with disasters and emergencies of any kind is essential for the introduction of nuclear power as it can be seen a base requirement for radiation protection that will be addressed in the next subchapter (2.4.5).

If such a comprehensive disaster management plan and infrastructure is in place including enough personnel to oversee its surveillance, a country will be awarded the maximum of 25 points for this category. If it has visible deficits that show that neither the protection of the population is guaranteed nor the fast response in case of emergency, the country in question will only get 15 points. Should the capability to react in a timely manner be doubted as no real disaster management infrastructure is in place, only five points will be allotted.

2.4.5 Radiation management and protection (25p)

"*Radiation protection concerns the protection of workers, members of the public, and patients undergoing diagnosis and therapy, against the harmful effects of ionising radiation*" (Nuclear Energy Agency, 2014). Regulatory legislation and programmes for the monitoring of and the protection against radiation have to be fully implemented by the time radioactive material is brought to the nuclear power plant. This includes not only the reactor design and on-site facilities to prevent radioactive release which are usually the operator's responsibility, but also radiation monitoring equipment all over the country, a functioning communication infrastructure as well as shelters and evacuation infrastructure for emergency response (International Atomic Energy Agency, 2007). The goal is to ensure a timely response to accidents, no matter whether they are minor ones or events that result in core-damage, as well as the safety of workers, the general population and the environment at any time.

If a country already employs ionised radiation in other fields like the medical sector or industry, a certain level of radiation protection infrastructure should already be in place (Nuclear Energy Agency, 2014). If this is the case and further measures for the introduction of nuclear power have been implemented, the country discussed will be awarded a maximum of 25 points. This includes a functioning communication infrastructure for national as well as international notification. If so far only basic radiation protection considerations have been taken, 15 points will be allotted, while deficits in both categories will net the country only five points.

2.5 Final score

The object of this study is to assess whether a country is capable of introducing and sustaining a nuclear power plant during the span of its lifetime. The three different indices that were introduced in the preceding subchapters are part of one overarching index called Critical Powers Index, which was developed by the author of this study. Its purpose is to encompass not only the issues addressed in the IAEA Milestone Approach, which are summed up in the Preparedness Index in this paper, but to also look at the basic considerations that should be taken before such an intricate and possibly dangerous project is being embarked on.

Each of the three sub-indices was allotted with one hundred points that can be achieved by a country if it meets all the requirements. However, as can be seen in the table below, for the Critical Powers Index weighting factors are introduced. The reason for this is that while all indices are important for the safe and secure introduction and maintenance of a nuclear power plant, some issues are more essential than others. The Preparedness Index will keep its one hundred points as outlined above. Its function is to assess whether the government of the country concerned follows the Milestone Approach to such an extent that the construction and operation of the nuclear plant can only commence once all legal, regulatory as well as issues concerning the management have been addressed. While it is essential that no inconsistencies remain, the success of the implementation of the nuclear power programmes depends on other preconditions.

These are covered by the Sustainability Index. Its aim is to comment on the status of development in the country concerned. To successfully build and sustain a nuclear power plant, certain preconditions have to be met; above all a functioning infrastructure should be present. Furthermore, if the countries in question rely too much on outside help to operate and finance their plants, they not only become dependent on others, but will also be slow to cope with emerging problems should they arise. Education and the capability of the domestic industry to support the nuclear programme with personnel and components are equally important, yet cannot be implemented within a short time period. The issues addressed in the Sustainability Index seem basic, but it is exactly because of this reason that they should be most central when introducing a nuclear power programme. Thus I gave the index a weighting factor of 2, which increases its maximum points to two hundred.

For the third index, the Emergency Preparedness Index, I chose a weighting factor of 1.5. The ability to both prevent and cope with nuclear emergencies is absolutely necessary for the protection of the country's population and the environment. While big nuclear accidents are rare, if they happen a fast and pre-planned response needs to be achieved. Nevertheless, the capability to deal with emergencies and disasters also largely depends on a functioning infrastructure and investments made in education and training of the population. 150 points will be awarded for the Emergency Preparedness Index if the country's analysis shows that it is stable and has a well-elaborated disaster management with enough hospitals and adequately equipped shelters to protect its people in case of a nuclear accident.

Adding up the adjusted points from all three indices, the maximum that can be reached is 450 points. In such a case the country concerned is well-prepared to not only build a nuclear power plant but also to maintain and sustain it and deal with all other issues including waste and emergency management. To judge how many points are sufficient enough to carry out the government's plan to introduce nuclear power is more difficult. After a long consideration I decided that at least sixty percent of the maximum score should be reached, which would be 270 points. However, this figure shows only the overall score of the analysis and not in which categories it was earned, which is why I also argue that at least sixty percent (120 points) should be reached in the Sustainability Index to guarantee at least a minimum degree of self-sufficiency and development. If this condition can be met in combination with a final score of at least 270 points, then the country in question should be given consent and support by the international community to proceed with the nuclear power programme.

Table 1 Critical Powers Index

Index	Points	Sub-index	Points	Weighting factor	Sum
Preparedness Index	100			1	100
		Laws	25		
		Regulatory authorities	25		
		Site selection	25		
		Commercial management	25		
Sustainability Index	100			2	200
		GDP/HDI	10		
		Economic development/ Quality of infrastructure	30		
		Industrial development	20		
		Financing	20		
		Human resources /education	20		
Emergency Preparedness Index	100			1.5	150

		Political stability	25		
		Health care	25		
		Disaster management	25		
		Radiation protection/management	25		
					450

3. Analysis of Japan's and Sudan's nuclear power programmes

3.1. General

In this part of the study I will use the Critical Powers Index that was presented in the previous chapter for the analysis of two nuclear programmes. First, I will use it to characterise the nuclear power programme of Japan, a country that has a long history with nuclear power both in the positive and negative sense. After calculating the country's final score, I will then continue with the analysis of Sudan. The African country has embarked on an ambitious plan to introduce their own nuclear power programme by 2019 (Gaafar and Mukhlis, 2012), and the purpose of this study is to assess whether Sudan, as a representative of the many developing countries that want to invest in nuclear power on their national soil, is capable of building, operating and sustaining a nuclear power programme.

3.2. Japan's nuclear power programme

3.2.1 Basic overview of the Japanese nuclear power programme

Japan, an island nation in East Asia with a population of 127 million people, is the third largest economy in the world (CIA World Factbook, 2014a). The country is characterised by a scarcity of natural resources for the generation of energy, which results in a high dependence on energy imports from abroad, above all the import of fossil fuels from the Middle East and other less stable regions. In 2014 Japan had to import close to 84 percent of its primary energy demand, a figure that had risen sharply in the years after the Fukushima Daiichi nuclear disaster and the subsequent shutdown of all nuclear power plants (World Nuclear Association, 2014a).

Japan began investing in nuclear power in the 1960s already, despite being the only country to ever have been hit by nuclear weapons in August 1945. Nevertheless, the Japanese government pledged its commitment to the use of nuclear power for peaceful use only and started the operation of its first reactor in the town of Tsuruga in 1966. It was not until the first oil crisis hit the Japanese economy hard that the government decided to make nuclear power a strategic priority to reduce vulnerability to similar events and to increase self-sufficiency (International Atomic Energy Agency, 2011).

By the end of 2010 Japan had more 54 reactors with an installed capacity of 46,821 MWe (Megawatt electrical), which contributed around thirty percent of the country's electricity demand and close to 14 percent of its primary energy mix in 2008. To further increase self-sufficiency and the reduction of greenhouse gas emissions, the Japanese government had planned to focus even more on nuclear energy in the future, with policies enacted to reach up to sixty percent of all primary energy in 2100 from nuclear power. However, after the Fukushima accident in 2011 and the subsequent backlash of the public, these plans were discarded intermittently and have now been adjusted downwards. While the future of nuclear power in Japan was uncertain the last few years, the newest version of the Basic Energy Plan, which was adopted in April 2014 and includes a forecast for the next twenty years, reaffirms the important role Japan's reactors play for the provision of base-load power, stating that they are needed to ensure a stable energy supply (ibid.; World Nuclear Association, 2014a).

Disregarding the Japan Power Demonstration Reactor, a boiling water reactor prototype that was operated between 1963 and 1976, the first commercial reactor that was introduced in Japan was a gas-cooled one imported from the United Kingdom. Afterwards, only light water reactors (LWRs), both pressurised water reactors (PWRs) and boiling water reactors (BWRs), were built. Japan has continuously conducted research to improve reactor and safety design, starting the development of Advanced Boiling Water Reactors (ABWRs) with international co-operation in 1978. At present, Japan is actively developing newer reactor types like Fast Breeder Reactors (FBRs) and High-Temperature Gas-Cooled Reactors (HTGRs) (International Atomic Energy Agency, 2011).

3.2.2 Preparedness Index: Japan

Legislative framework of the Japanese nuclear power programme

The first national law the Japanese government implemented when it formulated the plan to embark on a nuclear programme was the Atomic Energy Basic Law of 1955. It presents the basic considerations for the use of nuclear power in Japan, first of all the security of energy supply, while stressing the commitment to use the technology for peaceful purposes only (Organisation for Economic Co-operation and Development, 2011). This law laid the foundation for the Japanese nuclear power programme and subsequent legislation in this field.

Other important legal frameworks were implemented in the years after the implementation of the Atomic Energy Basic Law, three of them being of special importance: the first one is the Law for the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors, commonly referred to as the Regulation Law, which stipulates the necessary safety regulations as well as the operator's responsibilities and obligations. In it the peaceful use of nuclear power and nuclear material is being stressed as well. The second one is the Law concerning the Prevention from Radiation Hazards due to Radioisotopes, etc., abbreviated as Prevention Law, and the third the Law for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors. All these three laws were implemented in 1957, have been revised and amended ever since and address the main issues of a nuclear programme (Prime Minister of Japan and His Cabinet, 2011; Ministry of Economy, Trade and Industry, 2003).

In addition, a number of other laws have been implemented to establish a comprehensive national legislation ensuring nuclear safety. The Electricity Business Act regulates the country's electricity business as a whole, with safety procedures and regulations that include nuclear power generation as well. Furthermore, a licensing and inspection system for commercial reactors has been set up with which the operator has to comply on all accounts if he wishes to build a new plant. As for environmental protection standards, despite working towards becoming a pioneer in the field ever since the 1970s, the Environmental Impact Assessment Law, which also includes mandatory Environmental Impact Assessments for any type of power plant, has only been implemented in 1997, amending legislation for site selection that was in force up to that time. Legislation dealing with the disposal of spent fuel was drafted even later, the Law on Final Disposal of High-Level Radioactive Waste came into force in 2000 only (Organisation for Economic Co-operation and Development, 2011; Ministry of Economy, Trade and Industry, 2003).

On the international scale, the Japanese government has been at the forefront of non-proliferation and nuclear disarmament. It has been one of the 57 countries to become members of the International Atomic Energy Agency in its founding year of 1957.

As the only country up to the present day to ever suffer from atomic bombing, the government implemented a strict anti-nuclear weapon policy which banned their possession, manufacturing as well as their introduction on Japanese soil – the so-called Three Non-nuclear principles. While these principles were later revised as Japan came under the "nuclear umbrella" of the United States in the 1960s, the Japanese government nevertheless signed the Nuclear Non-Proliferation Treaty in 1970, ratifying it six years later on June 8th, 1976 (United States Department of Defense, 2009; Pike, 2011).

In international conferences the Japanese government stresses the importance of the IAEA safety regime and the advantages of the indefinite expansion of the NPT in 1996. The country also made an effort to win other IAEA member states for the conclusion and universalisation of the Additional Protocol at the beginning of the new millennium. To set an example, the Japanese government was the first country utilising nuclear power for electricity generation to sign the AP in December 2009 as a first step to promote this programme for extending and strengthening the previous safeguards agreements. To reach this goal, the country founded and held a series of seminars, hosting, for example, the "International Conference on Wider Adherence to Strengthened IAEA Safeguards" in 2002 as well as nine "Asian Senior-level Talks on Non-proliferation" (ASTOP) since the year 2003 (Tarui, 2008; Ministry of Foreign Affairs, 2004).

When it comes to both national as well international legislation for the introduction and continuation of a nuclear programme it can be said that the Japanese government successfully managed to build a comprehensive framework that is reviewed and amended in regular intervals ever since the introduction of the Atomic Basic Energy Law in 1957. While a revision of its constitution and a turning towards a nuclear weapon programme could hurt Japan's reputation and lead to severe problems on the international scale; as such a move would be in breach of international treaties and protocols, so far this has not happened. As the Japanese legislative framework can be seen as overarching and comprehensive, the maximum of 25 points for this category will be awarded.

Regulatory authorities

Following the implementation of the Atomic Energy Basic Law, the Japan Atomic Energy Commission (JAEC) was set up based on this law at the beginning of 1956. Its role was decided to be the implementation of "*policies for deliberately pursuing these goals or nuclear energy policies in a democratic manner*" (Japan Atomic Energy Commission, 2014). It is part of the Cabinet Office and has its own legislation under which it operates, the Law for the Establishment of the Atomic Energy Commission, which was implemented in December 1955. While it is tasked with the role of an advisor, it can propose its own recommendations, which then will be communicated via the Japanese prime minister or other agencies working in the nuclear field. Any of these agencies or ministries also have to consult with JAEC on questions concerning regulatory and licensing activities (Organisation for Economic Co-operation and Development, 2011). In addition to its functions on the domestic stage, which include policies on nuclear energy as well as training of staff and professionals and the co-ordination between agencies and ministries involved in the nuclear industry, JAEC is also active internationally. It collaborates with the IAEA as well as the Forum on Nuclear Cooperation in Asia (FNCA) and the Global Nuclear Energy Partnership (GNEP) among others (Japan Atomic Energy Commission, 2014).

In addition, a number of Japanese ministries have been given regulatory tasks, the three most important ones being the Ministry of Economy, Trade and Industry (METI), the Ministry of Land, Infrastructure and Transport (MLIT) and the Ministry of Education, Sports, Science and Technology (MEXT). METI, established after the governmental reform in 1999, is tasked with ensuring an efficient and stable energy supply in Japan, for which nuclear energy is deemed necessary. The ministry furthermore oversees the licensing of all stages of the nuclear fuel cycle, starting with milling to the operation of the reactor to waste management and disposal. In addition, it also administers safety regulations and works in the field of policy making. The Nuclear Waste Management Organisation (NUMO) which should find options for the final disposal of high-level waste was set up in 2000 by MEXT (Organisation for Economic Co-operation and Development, 2011).

MEXT, on the other hand, is tasked with governing the scientific and technological aspects of the nuclear industry, including research and development of technologies, policy preparation and implementation, as well as safeguards, safety regulations and third party liability for nuclear accidents. Furthermore, any nuclear materials and radioisotopes that are not used in reactors and other fuel cycle facilities are the responsibility of MEXT. For the transport of spent fuel and other kind of nuclear waste originating from nuclear power plants MLIT is responsible (Organisation for Economic Co-operation and Development, 2011).

Both the governmental reform of 1999 as well as regulatory rearrangements in the aftermath of the Fukushima accident brought changes to the organisational structure. While the roles of the three ministries have remained the same, a new, independent Nuclear Regulation Authority (NRA) was set up under the Ministry of the Environment in mid-2012.Headed by a chairman and four commissioners, the former Nuclear and Industrial Safety Agency (NISA) and the Nuclear Safety Commission (NSC) were both incorporated in the NRA to streamline safety, security, and safeguards issues. Furthermore, its responsibility is deciding on whether reactors can be restarted. The NRA's core values are independence as well as high transparency, the latter having been a point of criticism of its precursor agencies (Yamada, 2013).

As for carrying out the inspections of nuclear reactors and other nuclear facilities, the Japan Nuclear Energy Safety Organisation (JNES) was tasked with that function since its establishment in 2003. However, in September 2012 a law was passed to incorporate JNES into the NRA to further streamline the regulatory structure; the merger was carried out in March 2014 which greatly enhances the competence of the NRA (World Nuclear, 2014a).

Despite its several organisational changes in the past, the Japanese regulatory authorities have been comprehensive and well-established since the implementation of the Japan Atomic Energy Commission in the 1950s. While in the past tasks were distributed among a high number of different ministries and agencies, the latest reform in the aftermath of the Fukushima accident shows a positive trend towards streamlining assignments and roles to achieve a higher efficiency and expertise in the field, while at the same time the lesson to ensure more transparency to regain the trust of the Japanese population seems to be have learned. Because of this reasons I award the Japanese nuclear power programme with the maximum of 25 points for this category.

Site selection

As a country located in a region with high seismic activity, the careful evaluation and selection of a site on which a nuclear power plant can be constructed is of essential concern. The Japanese government bases its basic site selection concept on Article 17[2] of the Convention on Nuclear Safety of 1994 to which the country is a party. At present, three different assessments have to be made for every site that is taken into consideration: a) a safety impact assessment on natural phenomena and human induced external events to the nuclear installation, b) a safety impact assessment on the postulated accident of the nuclear installation to the general public in the vicinity, and c) an environmental impact assessments on the siting of the nuclear installation (Government of Japan, 2004).

Looking at national legislation, the Reactor Regulation Law demands that prevention of radiological hazards has to be taken into consideration. Furthermore, the Regulatory Guide for Reviewing Nuclear Reactor Siting Evaluation and Application Criteria was introduced in 1964 "*to examine the adequacy of the nuclear reactor siting conditions in relation to rare accidents*" (Nuclear Safety Commission, 1989). It also prescribes the dose the public can be exposed to, while at the same time establishing an exclusion area and low-population zone between the reactor and settlements (Government of Japan, 2004).

Ever since its implementation all nuclear power plants regardless of their proposed size are subject to an Environmental Impact Assessment (EIA) and have to adhere to the relevant provisions of the Electricity Utility Industry Law. An EIA has the advantage that it specifically intends for public participation, which has been, together with the lack of transparency, a main point of criticism in Japanese decision making processes. The drafting of an Environmental Impact Statement that has to incorporate both the results of the site study as well as comments from all levels of government and public discussion, is important for selecting a safe site that the inhabitants of neighbouring towns and settlements approve of as well. This can be considered an improvement to pervious siting procedures where public concerns have been largely

[2] See: International Atomic Energy Agency (1994): Convention on Nuclear Safety. International Atomic Energy Agency. [Online] http://www.iaea.org/Publications/Documents/Infcircs/Others/inf449.shtml - accessed: May 12, 2014.

ignored and mayors and landowners having been paid off for their support (Government of Japan, 2004; Aldrich, 2005).

Changes or alterations to construction plans at a time when an establishment licence has already been approved means that all site selection related factors have to be re-evaluated to ensure that a safe continuation of the operation can be guaranteed. Furthermore, if new findings might question the safety of the nuclear reactor and its surrounding facilities, a re-evaluation of the site which includes those new experiences has to be conducted as well. On the other hand, as Japan is an island country with a distance to its neighbours judged by its government to be sufficient to have only negligible impact on them even in case of a severe accident, their governments are not consulted in the site selection procedure (Government of Japan, 2014).

Earthquakes and tsunamis are the natural disasters that are most likely to have adverse effects to the operation of nuclear power plants in Japan. For this reason all parties concerned, the manufacturers, the authorities as well as the operator, collaborate on having the highest possible safety standards in these fields. Japanese nuclear reactors are built in close vicinity to the sea[3] to use sea water for cooling. Large underwater earthquakes can cause tsunamis, however, and thus bulwarks and other protective barriers have to be erected seaside to prevent the huge tidal waves to hit and potentially compromise the plant. A solid sealed containment structure can help prevent damage from tsunamis; what caused the disaster in Fukushima was the mistake of having electrical switchgear and backup generators in the basement of the building, which was flooded by the exceptionally high tsunami and as a result caused the core meltdown despite the plant shutting down as planned during the earthquake (World Nuclear Association, 2014b).

To reduce the impact of earthquakes, an important factor for site selection for Japanese nuclear reactors is to have a foundation made of hard rock and not sediments to minimise seismic movement. Japan has very stringent standards to ensure that the nuclear reactors are able to withstand damage from earthquakes and can shut down operation safely even if a very large one affects the plant. The guidelines are reviewed continuously, the latest one being released in 2006 with the title "Regulatory

[3] See: Cryptome (2011): Japan Nuclear Power Plants Eyeball. Cryptome Website. [Online] http://cryptome.org/eyeball/japan-npp/japan-npp.htm - accessed: May 24, 2014.

Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities", in which also the inspections that have to be conducted before restarting the plant after an exceptionally strong earthquake are defined (ibid.).

Japanese siting procedures for the construction of nuclear power plants can be evaluated as very thorough. While the country is known for its seismic activity, no major damage to nuclear facilities was caused by earthquakes alone in the past, which speaks both for the quality of site selection as well as the safety features (World Nuclear Association, 2014b). The process of site selection in Japan is elaborate and has been adapted in the past to now also include Environmental Impact Assessments, which gives the public the chance to voice their doubts and discontent, and ensure the environmental integrity of site and surroundings. It is because of these reasons that Japan is awarded the maximum of 25 points for this category.

Management issues

As already described above, there are a number of national authorities which are responsible for regulating as well as managing parts of the Japanese nuclear power programme. One of the main authorities tasked with management on the governmental level is the Ministry of Economy, Trade and Industry. It is responsible for overseeing both the licensing and inspection system, making sure that all laws and regulations to build and sustain a nuclear power plant are being observed. Without obtaining a licence from METI, no new commercial reactor can be constructed. The construction plan itself needs to be approved by the ministry based on the Electricity Business Act as well; the same perquisites apply for the fuel assembly design. Facility inspection already starts during the establishment phase; each step has to undergo a pre-service assessment which needs to be passed for the licensee to be able to continue the construction. Periodic inspections once the operation commences are designated with a default period of 13 months, which can be increased to 18 months after regulatory changes in 2009 (World Nuclear Association, 2014a).

The operators of the Japanese commercial nuclear power plants are the country's electric power companies. The Japanese provinces are divided into nine different zones, of which each has its own utility company. These nine are the Hokkaido Electric Power Co. (HEPCO), the Tohoku Electric Power Co. (TOHOKUDEN), the Tokyo Electric Company (TEPCO), the Chubu Electric Power Co. (CHUBU), the Hokuriku Electric Power Co. (HOKUDEN), the Kansai Electric Power Co. (KEPCO), the Chugoku Electric Power Co. (CEPCO), the Shikoku Electric Power Co. (YONDEN) and the Kyushu Electric Power Co. (KYUDEN). These nine are all members of the Federation of Electric Power Companies (FEPCO). A further private enterprise that operates its own nuclear reactors is the Japan Atomic Power Company (JAPC). Their duty is to comply with safety and security guidelines and to ensure physical protection for environment and staff for a safe operation and maintenance of the plant. For this reasons, the Japanese operators joint-funded their own training centres for plant operation training, which issue certifications assessing engineering qualifications (ibid.; International Atomic Energy Agency, 2011).

On the maintenance level, the Japanese companies Hitachi, Toshiba and Mitsubishi are suppliers of these services, together with international businesses like General Electric and Ebasco Services International which also make contracts with the Japanese electric utilities (International Atomic Energy Agency, 2011).

Despite the comprehensive system of authorities, operators and supporting companies, the Japanese maintenance structure has not been without criticism. TEPCO, which came under severe criticism in the aftermath of the Fukushima, admitted in 2002 of falsifying self-controlled inspection records in its nuclear installations to cover up deficiencies, including cracked core shrouds. The issue only became public after an allegation of a former inspection company employee. However, this was not the only accident that nuclear operators tried to cover up, which resulted in the erosion of the public's confidence in the safety of nuclear power in Japan (Government of Japan, 2004).

Looking at the Japanese fuel cycle, the country has developed a comprehensive domestic industry for the complete nuclear fuel cycle. The supervision of all activities concerning the enrichment, fuel fabrication, reprocessing and disposal lies with METI and the competent authorities under it. As Japan has no domestic sources of uranium, it has to be imported. In 2011, about one third of the country's demand were met by imports from Australia; other suppliers were Canada, Uzbekistan, Kazakhstan, and Namibia. To secure its future supply, the Japanese government actively seeks agreements with these countries and supports domestic companies to invest in mining installations abroad (International Atomic Energy Agency, 2011; World Nuclear Association, 2014a).

Apart from having to import uranium from international sources, Japan has developed a complete fuel cycle industry with all necessary technologies and installations in place. The policy to be independent from outside help for managing its fuel cycle had already been implemented in the 1960s to avoid supply disruptions due to possible uranium shortages. An important role for the research and development of fuel cycle expertise is the Japan Atomic Energy Agency (JAEA) that was established in 2006 from merging the Japanese Nuclear Cycle Development Institute (JNC) and the Japan Atomic Energy Research Institute (JAERI). On the front end, JAEA operates a plant at its Ningyo-toge Environmental Engineering Center in Okayama prefecture for refining and converting uranium, which includes a centrifuge enrichment plant for demonstrational purposes (Toki, 2012; Japan Atomic Energy Agency, 2013).

A commercial enrichment plant is currently in operation in Rokkasho-mura, which has been running since 1992. It utilises domestically developed technology and is expected to reach its peak capacity of 1.5 million SWU/yr (separation work units per year) in 2022. Nevertheless, in 2002 still eighty percent of all enrichment services had to be imported from abroad, which is the reason why another plant is planned as a joint project between the Russian corporation Rosatom and Toshiba. Fuel fabrication, on the other hand, is mostly done in Japan, the service being provided by private companies like Mitsubishi Nuclear Fuel Co Ltd. Fabrication of Mixed Oxide fuel (MOX) is done at JAEA facilities at Tokai (World Nuclear Association, 2014a; International Atomic Energy Agency, 2005a).

At the back end of the nuclear fuel cycle, the Japanese government has made attempts to extract as much extra energy from recycling unburned fuel residues in the form of MOX as possible. In the past, reprocessing was mostly done abroad in France and the United Kingdom, the transport of the fuel having been overseen by MLIT. In addition to a reprocessing plant in Tokai, which had been operational between 2002 and 2007, the Rokkasho Reprocessing Plant is currently the only domestic facility for nuclear fuel reprocessing in the country. Its owner is Japan Nuclear Fuel Limited, and its start of operation has been pushed back after a test phase from

2008 to 2014 (International Atomic Energy Agency, 2005a; The Federation of Electric Power Companies of Japan, 2014).

Disposal of radioactive wastes is specified by METI, which defines basic policies for each type of waste as well as disposal plans. In the course of implementing the Law on Final Disposal of Specified Radioactive Waste, the Nuclear Waste Management Organisation was established in 2000 with the aim of finding a storage site for the final disposal of spent fuel and other high-level nuclear wastes. While it was the private sector that set up the organisation, its activities are nevertheless overseen by METI, which also commands that stakeholders and the public have to be consulted in any underground storage site considerations (Nuclear Energy Agency, 2010).

Analysis of the management issues has shown that the Japanese authorities have developed a comprehensive management structure for its nuclear power programme and the nuclear cycle both on the front as well as back end. However, despite an elaborate allocation of roles and the implementation of mechanisms to ensure the observance of rules, past accidents show that the control and inspection system can be bypassed and reports falsified, which can have negative consequences for the safety of the nuclear installations. While the nuclear cycle activities can be generally judged as positive, especially since actions are being taken for the final disposal of high-level nuclear waste, Japan will only be awarded twenty points in this category; whether recent regulatory changes will yield better results, remains yet to be seen.

3.2.3 Sustainability Index: Japan

Gross Domestic Product and Human Development Index

Japan shows a very high level of development. It is a member of the Organisation for Economic Co-operation and Development (OECD) and is classified as one of the high income countries. In 2012 it had a population of 127.56 million, which exhibits shrinking tendencies after hitting its zenith in 2005. With a life expectancy at birth of 83 years in the same year, it is both one of the countries with the highest expectancy as well as one that suffers from severe population ageing (the country's total fertility rate was only 1.4 in 2014, one of the lowest globally). The country's GDP was USD 5.961 trillion in 2012, which corresponds with a per capita figure of USD 36,750 and puts Japan in the high income category (CIA World Factbook, 2014b; The World Bank, 2014a).

Looking at the Human Development Index, Japan has been one of the most developed countries since the index's introduction in 1990. In the version of 2013, it reached the tenth rank, being in the top quarter of the nations with a very high human development, scoring an overall value of 0.92. As already stated above, with a life expectancy of 83.6 years at birth the country tops this list in the HDI. When it comes to schooling, similar good results can be seen. The mean years of schooling in 2010 were 11.6, the expected years of schooling in 2011 15.3. With a Gross National Income per capita of USD 32,545 in terms of purchasing power parity of 2005, Japan ranks 11 in a global comparison. The country saw a continuous improvement of its human development since the introduction of the index. Next to its high educational achievements, the Japanese government spends 3.4 percent of its annual GDP on research and development to foster a positive environment for innovation and development of new technologies. The only area in which the country seems to lag behind compared to its high achievements in other categories is in the category of gender equality, where it only reached rank 21 because of the country's comparatively low female labour force participation rate of less than fifty percent (United Nations Development Programme, 2013).

Looking at the data presented above, one can judge that Japan enjoys a high level of development, with a population sufficiently educated to not only generate a high very high GDP (per capita) but also to be able to sustain a nuclear power programme with its knowledge and skills. Seeing as the country is globally also one of the richest and most developed countries, for this category the maximum of ten points will be awarded.

Economic development and infrastructure

In 2013 Japan was the third biggest economy in the world in terms of nominal GDP, outperformed only by the United States and the People's Republic of China. After World War II the Japanese government managed to generate a period of high economy growth by introducing market reforms, price controls and other policies to foster industrial productivity and investments. The so-called "Japanese miracle" was the result of these efforts, with growth rates of ten percent or more in the 1960s, and still five or four percent in the 70s and 80s respectively. One of the reasons why the economic expansion slowed down in the 1970s was because of the first oil crisis that hit the country hard in 1973, after which the government actively tried to reduce its dependency on fossil fuel imports to keep the industries going. While in that year 77.4 percent of the total primary energy supply was generated from oil, of which 99.8 percent of it had to be imported, in 2011 (before the Fukushima accident) this figure had been reduced to 49.7 percent (International Atomic Energy Agency, 2011; Ohno, 2006).

In the 1980s an asset bubble grew in the country as prices for property and real estate soared. Eventually, it burst in the beginning of the 1990s, dragging the country's economy into a long recession which, for the first time in Japan's post war economy, also brought a deflation with it. While still comparatively low compared to other developed nations, the country's unemployment rate rose and its income levels stagnated. Because of these reasons the term "Lost Decade" is often used for the 1990s in Japan. Economic growth continued to be small in the new millennium, the country falling into recession three times since 2008, the first being caused by a downturn in demand for Japanese exports due to the worldwide economic crisis in the same year. The current Prime Minister Shinzo Abe has made it his special goal to revitalise the Japanese economy, though it is the high government debt of 230 percent of the country's GDP that is posing a challenge now (CIA World Factbook, 2014a).

After a minus of 0.6 percent in 2011, the Japanese GDP has been growing again, albeit at modest rates of up to two percent. The unemployment rate, which is still low compared to other developed countries, has seen improvements as well, declining from 5.05 percent in the years 2009 and 2010 down to 4.07 percent in 2013. A bigger problem in the second decade of the new millennium was the ongoing deflation, which was present in seven years in the period between 2003 and 2013, the big exception being the year 2008, in which an inflation of 1.38 percent was present due to global economic disruptions. In 2013 the rate of deflation was 0.17 percent (Statista 2014a;b).

Japan exhibits typical traits of a developed country when looking at the employment of its population in the different economic sectors. In 2010 only 3.7 percent were employed in the agricultural sector, which is highly protected and subsidised to ensure a high degree of food security, even though sixty percent of the country's caloric intake have to be imported at present. Workers in the industrial sector constitute 25.3 percent of the working population. This sector is highly dependent on the import of raw materials and its energy consumption accounted for 47.2 percent of the total primary energy demand in 2002, despite continuous efforts to improve energy efficiency and to promote energy conservation. Employees in the services sector made up the majority with 69.7 percent in 2010 (Statista 2014c).

Recent policy changes under the new government, like the increase of the consumption tax to ten percent until 2015, helped the Japanese economy to end deflation and experience modest growth rates again. However, a continuously shrinking working population, high energy cost due to a higher reliance on imports after the Fukushima Accident and the high government debt still pose major challenges to government and the economy and need to be addressed in a careful manner (CIA World Factbook, 2014a).

Looking at the overall quality of Japan's infrastructure, the country ranked 12th in 2012 with a score of 5.9 of 7, and 14th in the following year with a score of 6. When it comes to railway infrastructure Japan is the leading country worldwide, having a modern railway system that is characterised by its high energy efficiency. A vast majority of all passenger transport is by trains, accounting for more than 22 billion passengers carried in 2011. Japan has a very high road density of 320 in 2009, which describes the "*ratio of the length of the country's total road network to the country's land area*" (Trading Economics, 2014). The overall quality of the road infrastructure is judged as quite good, with Japan ranking 12th in the Global Competitiveness Report ranking of 2013. However, the country is confronted with a rapidly aging road and social infrastructure, which will deteriorate at a fast pace if no countermeasures are taking. 65 percent of all road bridges will be older than fifty years in 2032, which is why the Ministry of Land, Infrastructure, Transport and Tourism together with other regulatory authorities is working on plans to counteract infrastructure aging in order to maintain and improve existing facilities. In terms of quality of airport and port infrastructure, Japan ranks as 37th and 30th respectively indicating potential for improvement (World Economic Forum, 2013; Ministry of Land, Infrastructure, Transport and Tourism, 2012; Trading Economics, 2014).

When it comes to its electricity system, the Japanese national grid is characterised as being an outlier. The country is split in two halves right in the middle of the main island Honshu. West of this "border" the country is standardised on a 60Hz frequency, while east of it 50Hz are used. This division has historical roots of the time when electric equipment was first brought to Japan at the end of the 19th century. For the transmission of electricity, however, this means that electricity generated in one of the two regions can only be moved the other region with great difficulties by using converters or HVDC transmission lines. While this was never an issue in the past, in the aftermath of Fukushima when eleven nuclear reactors in the eastern part of the country were shut down during the earthquake, it exacerbated the problems of electricity shortages and power rationing (Williams, 2011).

Due to these peculiarities and the fact that the grid is still waiting to be fully privatised, when it comes to the quality of its national electricity grid Japan only rank 34th in the global ranking, despite reaching a score six of a maximum of seven points. The problems in the aftermath of Fukushima encouraged the government to rethink the national system, it also implemented a series of legislation to reform the sector and break up the regional monopolies and to eventually implement a smart grid with a stronger focus on renewable energy generation to make up for the loss of electricity from fewer operating nuclear power plants. The problem of having in fact two different grids in one country will still need to be addressed in the future, though (Schlesinger, 2013; Sheldrick and Tsukimori, 2013).

The Japanese telecommunication infrastructure is one of the world's most advanced systems in this field. In 2004, the country lead the global ranking in terms of broadband internet access with the lowest fees for this service while providing the highest speed. In the same year, 89.5 percent of mobile phone users could access internet from their phones, which made Japan the country with the highest dissemination rates of mobile internet access. The telecommunication system is similarly advanced, with a penetration rate of 99.3 percent at the end of 2003, exceeding even the landline subscriptions. The Japanese government actively encourages the dissemination of new information technologies, pursuing the ambitious plan of making the country the most advanced IT nation in the world (Naito and Hausman, 2005).

The Japanese water infrastructure is also well developed. 97.3 percent of the population have access to tap water, the remaining 2.7 percent use unregulated water services like wells instead. However, in four rural prefectures the water supply coverage was less than ninety percent, which indicates a gap between urban and rural areas, which the government tries to alleviate in the future. A positive development is the low leakage rate of the domestic water infrastructure, which was only eight percent in 2008. Water shortages happen once every ten years, though climate change also has exasperated the problems in the past, as could be seen by a nation-wide shortage in 1994 that effected 16 million people (Ministry of Health, Labour and Welfare, 2014; Ministry of Land, Infrastructure, Transport and Tourism, 2008). Being an island nation, the Japanese reactors are all located near the sea to use salt water for cooling, which has the advantage of an endless supply.

Summarising the Japanese economic development as well as the quality of its infrastructure, it becomes apparent that the country is globally one of the leading nations in both categories. Despite suffering nearly two decades of little to no growth, the country's economy is still strong enough to support its people and keep its unemployment rate low. Looking at the infrastructural quality, Japan reaches top ratings for railways, its communication infrastructure as well as its water infrastructure. While facing possible over-aging, a problem the government is aware of by now, the road infrastructure is well developed too; and being an island nation Japan possesses a high number of ports to transport nuclear waste abroad for reprocessing if needed. Because of these characteristics the country will be awarded with a total of 25 of 30 points, as the economic problems are still not completely solved, yet the overall shape of Japan is rather positive.

Industrial development

Japan was the first country in Asia to industrialise. After the Second World War the nation and its industry lay in ruins, its rebuilding creating the Japan's economic miracle in the years to come that lasted until an asset bubble burst at the beginning of the 1990s. While the economy recovered only slowly ever since, Japan's industrial sector is still one of the most innovative and advanced ones in the world, specialising in automobiles, electronics and other high-tech gadgets, but also chemicals, steel and nonferrous metals, machine tools and ships are important fields in the sector: The earthquake followed by the accident in Fukushima in March 2011 had far-reaching negative effects on the domestic industry, hitting the automobile and semiconductor industry the hardest, which resulted in a service decline of six percent from which the country only recovers slowly (Economy Watch, 2013).

While the country had to import services and parts for building its first nuclear power plant in the 1960s from abroad, it has now developed an industry capable of providing all necessary services and technologies for constructing and maintaining a nuclear reactor without having to rely on outside help, while becoming one of the most important international providers. Three companies are the main suppliers of the Japanese nuclear industry: the first, Mitsubishi Heavy Industries Ltd. is providing the technology needed for Advanced Pressurised Water Reactors, while Toshiba Corporation and Hitachi Ltd., the other two, are responsible for supplying Advanced Boiling Water Reactors. In addition to those three companies, Japan also is renowned for its nuclear component manufacturers that not only supply the domestic, but also the international market: Japan Steel Works (JSW) is the leading supplier of heavy forgings with eighty percent of market share globally; Japan Casting and Forging Corporation (JCFC), Kobe Steel and IHI Corporation, which "*provides boilers, gas turbines, nuclear power equipment, BWR pressure vessels and containment vessels*" (World Nuclear Association, 2014c) are other companies that provide high-quality components for nuclear power plants (Kondo, 2010).

The companies in the nuclear industry also actively work together with regulatory authorities and research facilities to develop new technologies and reactor types to secure their high international standing. An example for this co-operation is the joint-development of a Long Operating Cycle Simplified Boiling Water Rector (LSBWR) of the Tokyo Institute of Technology and Toshiba Corporation (International Atomic Energy Agency, 2011).

Analysing the Japanese industrial capacities, it becomes evident that the country has developed a strong industrial base ever since the end of World War II, which is also capable of supporting the domestic nuclear industry to safely operate and sustain its nuclear power plants. Domestic manufactures, furthermore, supply other countries that established a nuclear power programme as well, which speaks in favour of the components' and technologies' quality. In consideration of these facts, I will award the Japanese (nuclear) industry the maximum of twenty points as it is fully developed and capable of sustaining the nuclear power programme without requiring any help from abroad.

Financing

Comparing the annual GDP of Japan, which has already been discussed further up in this chapter, with the average cost of constructing a nuclear power plant (USD 5-6 billion), it is evident that from this aspect building a new nuclear reactor puts no financial burden on the country's budget.

In fiscal year 2004, the Japanese government spent ¥ 471.8 billion on its nuclear power programme. This figure includes all nuclear-related activities like disaster prevention, the nuclear fuel cycle, waste treatment and disposal, as well as research and nuclear education. With a share of 31.1 percent of the expenses "coexistence with communities" was the most expensive activity, costing ¥ 146.9 billion in the same year (Japan Atomic Energy Commission, 2004). Compared to other governments, the Japanese one spends a much higher percentage of its budget on the research and development of new energy technologies, mainly to reduce its strong dependence on fossil fuel imports. Of its general research budget the nuclear industry received the lion's share of; 64 percent of R&D expenditures were allotted to nuclear energy in 2004, a figure than can amount to ¥ 500 billion (Ban, 2004; Japan Atomic Energy Commission, 2004).

About one third of the money is generated from general revenue; the other two thirds come from two separate special accounts. This system has been established in 1974 by former Prime Minister Kakuei Tanaka. The first of these accounts is for site establishment, while the other is for the diversification of electric power. The funds for both are collected via a special tax consumers have to pay as part of their electricity bill. The 31.1 percent of the budget used for "coexistence with communities" are meant to gain the support from a nuclear reactor's neighbouring population by the provision and maintenance of public facilities and other welfare benefits. As only less than ten percent of the budget for research and development comes from private entities, nuclear opponents often criticise that the amount of money spent by the government is mostly used to subsidise the nuclear power programme and buy the local support, without which it would not be economically feasible. For the year 2004 this means that the subsidy for nuclear energy was 1.5 yen/kWh. But while this means that nuclear energy is not as cheap compared to other primary energy sources, it nevertheless shows that the Japanese government has a long-term strategy for financing its nuclear programme, seeing as its nuclear budget also includes funds for waste treatment/disposal as well as continuous education and staff treatment (Ban, 2004; Japan Atomic Energy Commission, 2004).

Apart from the government's financial contributions to the domestic nuclear power programme, the operator also is required to provide a comprehensive strategy for funding and financing his plant. The first paragraph of Article 11 of the Reactor Regulation Law states: "*Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear facility throughout its life*" (Government of Japan, 2004). The government's first step to ensure that the future operator has the basic means to finance the project is the mandatory "Amount of Funds Required for Construction and Finance Procurement Plan" that needs to be submitted to the METI. Furthermore, to have the funds for decommissioning, the Ministerial Order of Reserve Fund for Dismantling Nuclear Power Facilities was enacted, which requires deposits both for plant decommissioning as well as the final disposal of treated waste. These regulations show that the Japanese authorities see nuclear power as a long-term project, which needs continuous attention and funds to cover all eventual expenses (Government of Japan, 2004).

Costs for the development and operation of a future underground site for the final disposal of nuclear waste are expected to be around ¥ 3,000 billion, the expenses for it being collected by taxing 0.2 yen/kWh from the utilities. As for the costs for decommissioning, plans are currently developed for the Tokai-1 reactor, which has been shut down in 1998 and is planned to be completely dismantled until 2018. Total expenses for the decommissioning, including cleaning-up of the site for re-use as well as waste disposal will amount to around ¥ 93 billion. Costs for other plants, for example the Fugen ATR, are expected to be in the same order of magnitude (World Nuclear Association, 2014a).

Despite these expenditures being high, the Japanese government and operators are capable both economically as well as strategically to shoulder this financial burden easily. From this point of view, no financial issues can be identified. What is causing a real problem, however, is the financing of the clean-up of the compromised Fukushima reactors. Estimated costs have continuously risen since the work on-site has started in the aftermath of the accident in 2011. In July 2014 the National Institute of Advanced Industrial Science and Technology estimated the costs to amount to up to ¥ 5.81 trillion, a figure triple its initial estimate. This puts a heavy strain on both the government as well as the responsible utility TEPCO, which is liable to cover compensation and costs for the clean-up of the surrounding areas. Furthermore, the timespan until the whole site has been cleaned and the plant decommissioned (which is expected to be the most expensive part) is expected to be forty years. This could mean that the costs increase even further. In addition to that, the shut-down of all the other nuclear reactors in the country caused the import costs for fossil fuels to rise dramatically, increasing Japan's trade deficit between 2011 and 2014 to ¥ 23.25 trillion, putting a heavy burden on the nation's budget and consequently also raising the electricity prices for the consumers (World Nuclear Association, 2014a; Takemoto, 2013).

Given these facts, the financing and funding plans of the Japanese government do not seem adequate anymore, especially since it will most likely have to shoulder the lion's share of costs as TEPCO has been nationalised in 2012 (KYODO, 2012a). Former financing schemes would have been sufficient if no accident had happened, given that the regulatory authorities are aware of the importance of having long-term financial prospects. However, after the Fukushima accident both the clean-up and compensation costs, as well as the growing trade deficit from soaring fossil fuel imports put a considerable strain on the Japanese economy and budget, which can have negative repercussions on the country's situation as a whole. Because of this reason the country cannot be awarded the maximum of twenty points for this category, but will be given 15 instead, as it is nevertheless evident that the basic capabilities to finance a nuclear power programme are met.

Human resource development and education

In international comparisons Japanese students have been showing top performances since the implementation of the tests, scoring high points in all fields, only being equal with or bested by Finland and other East Asian countries like South Korea and, more recently, the People's Republic of China. While changes in the last decade show that Japan lost points in reading and mathematics, scores in science have on the other hand risen. The national curriculum in mathematics and natural sciences has been judged to be one of the most demanding in the world (Organisation for Economic Co-operation and Development, 2012; National Center on Education and the Economy, 2014).

Responsible for the national curriculum is the Ministry of Education, Culture, Sports, Science and Technology (MEXT), which develops it together with the Central Council for Education and distinguished university professors. Science and mathematics education already starts in the third year of primary school, the first two years a course on "life environmental studies" is taught instead. While this general layout has not changed in the last years, an educational reform in 2009 increased weekly science hours; the same changes have been made for mathematics as well. In junior high school the science curriculum is divided into two fields, the first one being chemistry and physics, the second Earth science and biology. The focus lies on experiments in school-owned science laboratories and a "*scientific perception of nature*". In senior high school the students are given more freedom on choosing the topics discussed, though the focus on developing a strong scientific way of thinking is still present (Hays, 2008; Tsukahara, 2014; Goto, 2000). Natural sciences including mathematics thus play a significant role in the Japanese curriculum and Japanese students score high marks in international competitions which speaks for the quality of education in the country.

As for training and education for staff and personnel in the nuclear industry, the Reactor Regulation Law states the following in its Article 11 paragraph 2: "*Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities in or for each nuclear facility, throughout its life*" (Government of Japan, 2004). This asks for the involvement of both official governmental educational facilities as well as private training institutes and those of the license holder itself.

The Japanese university system provides students in tertiary education all over the country with undergraduate and graduate degrees in the nuclear field, from engineering over nuclear safety and security to fuel cycle research. A total of eleven universities offering degrees in nuclear engineering also accept applications from abroad, amongst others the prestigious Tokyo Institute of Technology and Kyoto University. Japanese universities also cooperate closely with national and international research and development institutes including the IAEA to ensure that the country can safely operate their nuclear power plants without having to rely on outside help (Japan Atomic Energy Agency, 2014a; Sugimoto, 2012).

In 2010 the Japan Nuclear Human Resource Development Network was developed with the aim of getting students interested in degrees in nuclear science, and to support those who pursue such a degree to get the best education possible and to eventually find employment in a domestic facility. The Network has representatives from academia, the government and the nuclear industry who all work together to ensure the best possible results. Furthermore, international cooperation and training courses for other Asian and less developed countries are also provided. Such seminars address all nuclear issues, including siting, safeguards training, plant safety as well as administrational courses (Sugimoto, 2012).

The Reactor Regulation Law requires that the operator in question possesses the skills and knowledge to operate a nuclear power plant, which has to be demonstrated already before the licence is being given by the government. Because of this reason each operator has its own training facilities and jointly manages testing centres with the other utilities throughout the country. Staff training is thus not only provided in educational institutions and government operated facilities but the plant owner as well (Government of Japan, 2004, International Atomic Energy Agency, 2011).

Currently, the most pressing issues concerning the human resource development are the public opinion which expresses as strong anti-nuclear bias after March 2011 and the concern that not enough nuclear scientists will be available in the future, now that the first generation of domestic experts has started to retire. In order to counteract this development the Japan Nuclear Human Resource Development Network started to focus more on information campaigns in primary and secondary schools (including both junior and senior high school) to explain the importance of nuclear power for Japan and do away with negative prejudice about this kind of energy source. The Nuclear Energy Institutes (NEI) provides material which can be implemented into the national curriculum for these reasons (Sugimoto, 2012, Nuclear Energy Institute, 2014).

The analysis of general as well as specialised education in Japan has shown that the country has a well-developed and comprehensive educational system for its children with a strong focus on mathematics and natural sciences. Its ranks in international competitions are representative of the quality of education in Japan. Furthermore, the country also has the capabilities to educate and train nuclear experts and staff in nuclear power plants without help from abroad. In addition to universities all over the country offering degrees up to PhDs in nuclear science and engineering, private training centres exist as well. A tight cooperation between governmental agencies and operators and training facilities ensure a continuous supply of human resources for the nuclear power programme. With respect to the quality of education and human resource development, Japan will be awarded the maximum of twenty points for this category.

3.2.4 Emergency Preparedness Index: Japan

Political Stability

Japan can be judged to have a good political stability. Looking at the Failed State Index of 2013, the country is ranked 156 from 178 (1 being the most unstable, 178 being the most stable country), which puts it in the second best category, stable. The country scored 36.1 points from 120, which is double the points the most stable country Finland reached in the same year. The worst scores Japan reached in three of the four social indicators, in the categories demographic pressures (5.4 points), refugees and IDPs (3.7 points) and group grievance (3.8 points). The main issues were the growing pressure from a rapidly aging population as well as the displacement of people because of the earthquake and accident in Fukushima in 2011. Further categories in which Japan has not scored so well compared to other OECD countries are poverty and economic decline (3.7 points), which can be explained by the continuous economic problems the country has faced since the burst of its asset bubble at the beginning of the 1990s, and external intervention (3.7 points), which is because of the presence of the US military on Okinawa. On the other hand, the rule of law is guaranteed, the security apparatus working as intended and the likelihood of terrorist activities and attacks is low. Ever since the elections in 2013, political stability in terms of not changing national leaders annually is likely to have been achieved again, too (Harlan, 2013; The Fund for Peace, 2013).

Despite not scoring top marks in comparison to countries like Finland and other Scandinavian states in all of the twelve indices analysed in the Failed State Index, Japan will nevertheless be rewarded the maximum of 25 points for this category. Rule of law is observed, the government is stable enough (despite frequent elections in the last years, these have been fair and transparent), and terrorist attacks on national soil are very unlikely. The only real issue present in Japan at the moment is the demographic pressure due to population aging. This, however, does not interfere directly with the safe and secure operation of a nuclear power programme, which is not considered a reason to award less than twenty points.

Medical infrastructure

The Japanese medical care system is one of the best in the world while at the same time being cheaper than many others. Compared to US Americans, Japanese people have to spend about half as much on medical treatment and healthcare while at the same time having a longer life expectancy. The health care system was introduced at the beginning of the 1960s and is characterised by the following factors: universal health coverage that is financed via insurance contributions and general tax revenue - less than 8.5 percent of the GDP, which is considered low compared to other developed countries; the government operates a so-called statutory health insurance system, which includes 134 different insurers, high-income earners can opt out from this in favour of private insurance, everyone else is obligated to be insured by one of the public insurance companies; there is a monthly cost ceiling in place for low-income people, which is ¥ 35,400, and cost-sharing is furthermore reduced for retirees and children (Thomson et al., 2013).

Nevertheless, the Japanese health care system has increasingly been faced with problems in the last years. First of all, the rapidly ageing and shrinking population reduces the number of people in the workforce which pay insurance and taxes to keep the health care system running. Because of this reason public spending has increased as well, despite still being low compared to other OECD countries. Secondly, while Japan generally can provide easy access to medical care even in more remote areas, the number of hospitals in the country has been decreasing. While in 1990 the number of active medical facilities in Japan was more than 10,000, it had been reduced to 8,749 in 2009, for which mostly bankruptcy was blamed. This kind of mismanagement also is also reflected when looking at the percentage of public hospitals spending more than earning in return, which came close to 64 percent in 2007. A shrinking number of hospitals and only two doctors per one thousand people, putting Japan on rank 27th of all thirty OECD countries, show growing problems for the national health care system, which will have to be addressed in the future (Kuchikomi, 2009; Organisation for Economic Co-operation and Development, 2013).

When it comes to disaster preparedness of Japan's nuclear infrastructure, additional problems become apparent. When the earthquake hit Japan on March 11th in 2011, five hospitals in the affected zone near the nuclear plants of Fukushima could not function properly. The Fukushima Medical University Hospital, a facility that has radiation exposure as one of its core capacities, failed to treat people exposed to radiation in a timely manner, while caring for injured persons first. At another hospital, the Futaba hospital, all staff was sent away, leaving patients behind that had to wait two days for the Japanese Self-Defence forces to come and evacuate them. From this it becomes apparent that emergency planning within the hospitals and health care facilities was either not prepared sufficiently for such an accident, or that personnel was overwhelmed by the fast influx of patients and the chaos surrounding it (Talmadge and Yamaguchi, 2012; ENENews, 2012).

Currently there are 13 provinces in Japan with commercial nuclear power plants. In each of them primary-response hospitals to deal with nuclear emergencies are located as well, like the one in Fukushima mentioned above. Of these hospitals, only those located within a ten kilometre radius of a power plant have to have emergency and evacuation plans in place, which applies to roughly 25 percent of them. Taking the facilities that are located within a twenty kilometres radius of the reactor into account, this figure rises to 42 percent, yet most of them have only the most basic contingency plans implemented. If an accident like Fukushima would happen at a different plant, evacuating hospitals and the provision of radiation treatment would be similarly difficult (ENENews, 2012; Talmadge and Yamaguchi, 2012).

The Japanese government now seeks to strengthen the hospitals' capabilities for emergency response as it became evident that medical facilities are not adequately prepared for nuclear accidents despite possessing the expertise and equipment for it. The country's Nuclear Regulation Authority now plans to designate hospitals outside of possible evacuation zones to provide emergency treatment for contaminated people in a timely manner to prevent a breakdown of medical care in case of emergency like it happened in the aftermath of Fukushima (ENENews, 2012).

In summary, the Japanese medical infrastructure can be said to be very well developed, providing one of the most sophisticated health care system of the world. Despite facing the problem of an aging population, the Japanese population can get quality treatment while paying less than other developed countries. The medical infrastructure is also prepared for nuclear accidents, having designated primary-response hospitals in all of the 13 provinces in which nuclear reactors are located. The expertise and equipment to treat patients with radiation exposure is available, however, during the Fukushima crisis it became apparent that there is a strong need for implementing comprehensive emergency and evacuation plans. In consideration of these facts, Japan will be awarded twenty points, as both basic as well as advanced medical infrastructure is present and only the emergency response has to be improved.

Disaster management

Because of its location in the Circum-Pacific Mobile Belt, Japan is a disaster-prone country with a lot of volcanic and seismic activity. Other environmental hazards like typhoons also occur at an annual rate. Taking these facts into consideration, the Japanese government takes disaster management in its country very seriously to secure people's life and property. The legislative foundation for disaster management in Japan is the Disaster Countermeasures Basic Act, which was implemented in 1961. It lays out a strategic and comprehensive system for disaster management and is complemented by a series of other regulations and laws including, but not limited to, the Act on Special Measures for Active Volcanoes of 1973, the Act on Promotion of Disaster Resilience Improvement in Densely Inhabited Areas of 1997, or the Disaster Relief Act of 1947 (Government of Japan, 2011).

Disaster Management in Japan takes place on three levels: the national level, the prefectural level and the municipal level. On the highest level, the continuous amending and implementation of the Basic Disaster Management Plans lies in the focus. The more regional and local authorities are tasked with implementing measures framed specifically for their needs. In total there are 24 government organisations involved in disaster management in Japan, including ministries and other high-level agencies, as well as 56 public and independent corporations like the Japanese Red Cross Society or the Bank of Japan. Since 2001 a Minister of State for Disaster Management exists. He is tasked with coordinating disaster management and reduction policies with other ministries and agencies. In addition to his role, the Cabinet Office now houses a Deputy Chief Cabinet Secretary for Crisis Management as well as the Cabinet Information Collection Center, which has a supporting role in disaster management (ibid).

Japanese disaster management distinguishes between man-made and natural disasters, the former including accidents like road disasters, aviation disasters or nuclear disasters. In total, eight accident disasters fall into this category. Natural disasters, on the other hand, describe earthquakes, volcanoes, storms and floods, and snow disasters. For both categories the Disaster Countermeasures Basic Act dictates three distinct steps to deal with (potential) accidents and disasters. The first step is the disaster preparedness and prevention. This includes observation and warning systems for weather events, earthquakes and volcanoes, as well as anti-tsunami/flood measures like bulwarks or high quay walls to prevent damage by water. The Japanese government spends a considerable amount of its disaster management budget (¥ 1.2 trillion in 2010) for prevention and preparedness measures together with financial support for research and development to further improve existing technologies. Furthermore, land conservation measures, which were allotted 62.4 percent of the disaster management budget in 2010, are of strategic importance for the prevention of disasters and the protection of lives and property as well. The second step in Japanese disaster management is the response to disasters and emergencies. If a disaster cannot be prevented and thus hits (parts of) the country, it is important to react in a timely manner. As it is vital to help the affected region as soon as possible to keep damages and loss of human life limited, the Japanese government has incorporated a comprehensive disaster management communication system: Communication between all parties is secured via satellite, which allows quick information sharing so that the government and supporting agencies get a fast overview of the situation in the affected area. The third step in disaster management is recovery and rehabilitation, which should happen as fast as possible to allow people to return to their normal lives within a short time period. This step includes reconstruction of the damaged public infrastructure, but also direct support to the affected population by means of subsidies, tax exemptions or low-interest loans. In the case of earthquakes, the Japanese government has furthermore set up an earthquake insurance system, which allows people working in forestry, agriculture and the like to be compensated for their losses (ibid.).

Evacuations are also part of the Japanese disaster management procedures. Generally, disaster victims are allowed to start evacuating on their own when a disaster is imminent or has just hit, though the responsible authority of the affected area can also issue an evacuation order. The Guidelines for Producing a Decision and Dissemination for Evacuation Advisories and Orders were published in 2005 and recommend that municipalities prepare an evacuation manual for their inhabitants to follow in case of emergency, as past natural disasters have shown that self-evacuation activities did not work as intended. To ensure the safe evacuation of elderly people a framework was set up in the same year to prevent leaving people behind in case of emergency. Furthermore, for the case of disasters affecting larger regions, wide-area support mechanisms have been set up including the possible dispatch of the Self-Defence Forces in case regional authorities and teams are overextended (ibid.).

The Great East Japan Earthquake that was followed by a tsunami of 15 metre height and the subsequent accident at Fukushima Dai-Ichi put the Japanese disaster management to an unprecedented test, illustrating the strengths and weaknesses of the system. Earthquake management was judged to be very good, as this is one of the main fields in which the Japanese government invests to keep its public safe. Because of yearly public drills the population was prepared how to act in case of an earthquake and warnings were broadcast immediately. Earthquake-safe building methods also minimised the damages from the earthquake. The management of the tsunami was already less than perfect, however. The tsunami early warning systems did function as planned. However, bulwarks and wave breakers were not designated for a wave of that height, which meant that the tsunami was not prevented from speeding inland. As a result of a breakdown of the communication infrastructure, the government had difficulties reacting in an appropriate manner immediately. It did, however, mobilise 100,000 troops for first response and rescue and search missions for which it should be credited. When it comes to the subsequent nuclear disaster, the Japanese government's response can be said to having been subpar. Several shortcomings in management can be identified, which stem from the breakdown of communication infrastructure on one hand, which made it impossible to immediately know what had happened at Fukushima Dai-Ichi, and the apparent difficulty to improvise when faced with such an unprecedented triple-disaster on the other hand. The aftermath of the accident also showed a severe lack of transparency from all parties involved, further undermining the trust of the population that was keep in the dark for a long time. While an accident like this has a very low probability and thus would not be considered in models, the Japanese government did show severe governance shortcomings, which compromised the otherwise well-developed disaster management system (Kaufmann and Penciakova, 2011).

Generally speaking, it can be said that the Japanese disaster management system is well established, incorporating all three essential steps: prevention, disaster response, and recovery. Disaster management plans are continuously amended and adapted, taking into account a series of possible disasters for which comprehensive prevention and coping strategies have been devised. Measures for prevention are strong, as is the communication system that has been devised to allow an immediate response even in case of large-scale disasters. In light of the Great East Japan Earthquake of March 2011 and the accompanied tsunami, the World Bank recommends the incorporation of measures for "*low-probability and impact multilocation hazards*", which have not been paid enough attention in the past (The World Bank, 2012). In addition to that, however, governance and transparency will also need to be improved to allow fast and sufficient responses to more-dimensional disasters in the future. Revisions to the Disaster Management Basic Act have already been made to that effect by now. Nevertheless, the Japanese disaster management system can be judged to be comprehensive when it comes to basic considerations. It is very well prepared for earthquakes and, to some extent, tsunamis and other disasters as well. Improvements need to be made for low-probability events including nuclear accidents, as their impact can be catastrophic despite them being very rare. In face of this, the Japanese disaster management will be awarded twenty points for this category.

Radiation management and protection

The most important laws for radiation management and protection in Japan are: the Reactor Regulation Law, especially its Article 15 and 16, the Electricity Utilities Industry Law and the Industrial Safety and Health Law, etc., as well as specialised laws like the Act on Special Measures Concerning Nuclear Emergency Preparedness, the Industrial Safety and Health Act, and the Regulation concerning Prevention from Radiation Hazards due to Ionizing Radiation. Furthermore, recommendations of the International Commission on Radiological Protection (ICRP) are incorporated into Japanese domestic legislation as well to adhere to international quality standards (Government of Japan, 2004; Organisation for Economic Co-operation and Development, 2011; Japan Atomic Energy Agency, 2014b).

The first law to be established in this field was the Law concerning Prevention from Radiation Hazards, the so-called Prevention Law that was implemented the same year as the Reactor Regulation Law. Its goal is to regulate the handling and disposal of radioisotopes and equipment utilising any kind of ionising radiation to ensure public safety. To be allowed to handle such radiation-generating sources, a licence has to be requested from the Ministry of Education, Culture, Sports, Science and Technology. The Prevention Law furthermore introduced an inspection systems as well as training courses for radiation protection supervisors in 1980 (Organisation for Economic Co-operation and Development, 2011).

Exposure doses are regulated by both the Prevention Law as well as the Rules for Commercial Power Reactors and the Dose Limits Notification, depending on which field is concerned. For radiation protection in reactors the legislations demands the establishment of a radiation controlled area within the facility plus the observance of dose limits for staff and personnel who are exposed to radiation at their workplace. Different dose limits are prescribed for personnel, including effective and equivalent limits, and special limits for female and pregnant staff. For emergency personnel dose limits are "per incident" after which they must not be exposed to radiation for a fixed period of time. Dose limits for the general public are still lower, allowing a maximum of 1 mSv (millisievert) per year (Government of Japan, 2004).

To measure radiation exposure both in nuclear facilities themselves as well as in their surroundings monitoring stations are employed. Depending on the type of radiation to be measured different survey meters are used: Remcounters, Geiger-Müller meters, or scintillation-type survey meters for monitoring inside reactors, whereas for environmental monitoring meteorological instruments as well as dust monitors, dosimeters and land samples are employed to observe radiation (Japan Atomic Energy Agency, 2014b; 2014c).

Operators and license holders are instructed to employ continuous efforts to reduce the amount of radiation their personnel is exposed to strengthen work safety and staff health. To achieve this goal, projects for a large-scale modernisation in reactors have been implemented, targeting primary loop recirculation piping and the replacement and repair of core shroud piping. However, while dose reductions are achieved once the improvement works are completed, collective doses per reactor even increases slightly during replacement. Dose equivalents and collective doses have to be checked on a daily basis by the operator. In addition, the Radiation Workers' Registration Center of the Association of Radiation Impact, which was established in 1977, helps in keeping track of exposure doses of personnel working in more than one radiation facility at the same time (Government of Japan, 2004).

Radioactive material discharge is also monitored; the focus lies on protecting the public in the vicinity of where the discharge happened. "*In the Dose Target Guide for the Public in the Site Vicinity, the NSC has prescribed the numerical guide of 0.05 mSv, one twentieth of the dose limit to the public, in order to reduce dose for the public due to discharge of radioactive material to the environment during normal operation of a nuclear installation as low as reasonably achievable*" (Government of Japan, 2004). The ultimate goal is to keep the dose of the discharge well below the numerical guide and to further reduce the overall discharge of liquid and gaseous wastes. For this task further monitoring stations are installed at the facilities to control exhaust air and water discharge (Japan Atomic Energy Agency, 2014b).

Environmental monitoring is another important part of radiation protection and management, which not only the licence holder is tasked with, but the government and its responsible authorities as well. Monitoring stations are placed both in the direct vicinity of nuclear facilities to monitor public exposure in those areas, but also at specific locations all over Japan for nuclear emergencies. Incorporating meteorological data is of special importance to observe and even predict the spread of radiation in case of excessive discharge, as was the case at Fukushima Dai-Ichi. The System for Prediction of Environment Emergency Dose Information (SPEEDI) has been developed for dose assessment in real-time in case of emergencies and is utilised by the Ministry of Education, Culture, Sports, Science and Technology. It is interlinked with local governments, the national weather organization and the Science and Technology Agency of Japan to allow quick communication among these entities in case of emergency (Chino, Ishikawa and Yamazawa, 1993).

While the Japanese radiation monitoring network can be seen as comprehensive, in the aftermath of the Great East Japan Earthquake problems arose as the responsible authorities withheld data on radiation spread and contamination from the public, despite having received reliable information from SPEEDI immediately after the accident at Fukushima. This not only shows the lack of transparency that was already addressed in the previous sub-category, but it also resulted in residents being exposed to more radiation than would otherwise have been the case (KYODO, 2012b).

A further shortcoming of the Japanese radiation protection and management system is the lack of radiation shelters. During the Fukushima accident people were brought to hastily designated shelters around the evacuation zone, which were not fit for nuclear accidents. This constitutes a lack of consideration for both small and big nuclear accidents. Only in 2013 the NRA announced the implementation of fifty nuclear fallout shelters for people living in the vicinity of nuclear power plants, which will be equipped with all the necessary technology like special ventilation systems and decontamination equipment at their entrance. Furthermore, despite possessing the skills and capabilities to deal with radiation exposure (and also offering radiation therapy and the like), the medical care response to the accident was less than perfect considering there were no hospitals specifically designated with decontamination and the treatment of patients with radiation exposure. During the Fukushima accidents four of the six medical facilities in the prefecture tasked to treat exposure to radiation were located within the evacuation zone and of those only two were adequately equipped for treatment. Only in 2013 the Japanese government decided on introducing special “nuclear disaster hub” facilities to allow a focussed and fast treatment in case of a nuclear accident and radiation exposure (Oiwa, 2013; SimplyInfo, 2013).

The aftermath of Fukushima brought with it a clean-up campaign of unprecedented scale. In addition to the on-site measures taken to reduce further release of radiation and to eventually decommission the damaged reactor in the future, the Japanese government has also implemented measures to decontaminate the surrounding environment to allow the eventual resettling of the affected areas. For this the Act on Special Measures Concerning the Handling of Radioactive Pollution was implemented in 2011, which tasks the Ministry of the Environment (MOE) with the decontamination issues. Together with continuous radiation monitoring, decontamination measures are being implemented in one hundred municipalities in a total of eight prefectures. The steps taken are in accordance with recommendations from the NRA and the ICRP and include the reduction of radiation doses the residents are exposed to by means of water treatment as well as soil and plant removal. As this might cause other environmental problems, the IAEA cautions the government to only clean up as much as to not turn the area into a barren wasteland (Bird, 2012; Ministry of the Environment, 2014).

In summary it can be said that the Japanese radiation protection and management system is quite comprehensive. The country possesses the skills and capabilities to monitor radiation both within reactors as well as all over the country. Furthermore, there is firm legislation in place that limits exposure doses for the general public and power plant personnel, which are continuously monitored. However, the Fukushima accident showed the shortcomings of the system. No nuclear fallout shelters were in place and hospitals failed in providing adequate primary response treatment despite the country’s medical system possessing the skills and technologies to do so. Only after these shortcomings became apparent in the aftermath of the accident, the Japanese government implemented policies to amend their radiation protection management. The Fukushima disaster also demands a clean-up of the environment, which the Ministry of the Environment is now tasked with. Special legislation has been implemented for this purpose; clean-up efforts have already started. Despite its long history with ionising radiation, the Japanese radiation management and protection system proved to be insufficient in the face of a nuclear accident, which is why Japan will be awarded twenty points for this category, as new legislation has already been implemented by now.

3.2.5 Final score: Japan

Table 2 Critical Powers Index: Japan

Index	Points	Sub-index	Points	Weighting factor	Sum
Preparedness Index	95			1	95
		Laws	25		
		Regulatory authorities	25		
		Site selection	25		
		Management issues	20		
Sustainability Index	90			2	180
		GDP/HDI	10		
		Economic development/ Quality of infrastructure	25		
		Industrial development	20		
		Financing	15		
		Human resources /education	20		
Emergency Preparedness Index	85			1.5	127.5
		Political stability	25		
		Health care	20		
		Disaster management	20		
		Radiation protection/management	20		
					402.5

The above table shows the overall Critical Powers Index for Japan. With an overall score of 402.5 of a maximum of 450, the country is well-prepared for operating and maintaining its nuclear power programme. Japan scores best in the Preparedness Index, earning a total of 95 of one hundred points, which shows that it follows the IAEA Milestone Approach to a sufficient extent and has all the necessary framework conditions needed for the introduction of a nuclear programme in place. The only possible improvements are in the management issues category, as events in the past have shown that the actions of the licence holders have not been controlled sufficiently.

In the Sustainability Index Japan is awarded 180 of a total of two hundred points, which again shows that the overall situation in the country is favourable for maintaining nuclear power plants in a safe and secure way. The domestic infrastructure is well-developed and ranks first in several areas globally. However, as the country has been plagued by economic troubles the last two decades, which also reflect on its budget, the maximum points for this index could not be awarded despite otherwise favourable conditions.

The third index, the Emergency Preparedness Index, is Japan's relative weakness. While the country is politically stable and the probability of terrorist attacks is exceptionally low, it suffers from several shortcomings in its ability to adequately react to accidents and disasters. The problems thus lies less with a lack of skills or technologies, but the risk and disaster management plans and the taking into account of low-probability events. These shortcomings became apparent during the Great East Japan Earthquake that was followed by a tsunami and the accident at Fukushima, highlighting the need for a more comprehensive strategy for dealing with unforeseen nuclear events. The Japanese government has implemented new legislation ever since, which can be seen as an improvement in these categories; nevertheless, the country is only awarded with 127.5 of the possible 150 points for the Emergency Preparedness Index.

Adding the three indices up, Japan receives a final score of 402.5 points, showing that the country, despite depicting room for improvement in a few categories, is well capable of operating and maintaining its nuclear power programme.

3.3 Sudan's nuclear power programme

3.3.1 Basic overview of the Japanese nuclear power programme

Sudan is a country in north-eastern Africa with a population of 35,482,233 and an area of 1,861,484 km², making it the 16th largest country in the world and 3rd largest one in Africa. Recently, in 2011 a part of the country in the south seceded after years of strife and civil war. Sudan and South Sudan both possess sizable reserves of natural gas and crude oil, which are both causes for fast economic development as well as for conflict between the two countries. The oil production has been in decline in Sudan in the last years, indicating a maturing of the oil fields and reflecting the fact that about seventy percent of the oil resources were lost with the independence of South Sudan. However, together with the mainly Asian companies that are active in the country the Sudanese government is planning to increase production again in the near future to finance its economic and social development. (U.S. Energy Information Administration, 2013; Gaafar and Mukhlis, 2012; CIA World Factbook, 2014c).

As is the case with most developing countries, Sudan is characterised by a rapidly increasing demand in primary energy to support the growing population and economy. Because of the availability of local sources, energy consumption is dominated by fossil fuels, especially oil, which made up 93 percent of the primary energy mix in 2004, constituting an increase of seven percent in the previous two decades. At the same time the share of energy generated from hydropower decreased from 14 to seven percent in the same time span. Hydropower made up 66.3 percent of all electricity generation in 2010 together with three percent of electricity from other renewable sources, however, indicating that crude oil is mostly used for fuelling the industry. These figures do not include the use of biomass for energy generation, however, which is used in most parts of the country where people still live off the electricity grid (South Sudan-American Friendship and Trade Association, 2011).

The country is mostly independent from fuel imports (apart from jet fuel); in fact oil exports represented 65 percent of the revenue for Sudan in 2008. Nevertheless, the demand for energy rises rapidly in the country, for which reason the government in Khartoum has embarked on the journey to introduce its own nuclear power programme. The first plan was formulated in 2007, when the nuclear power programme was formally initiated by the Ministry of Energy and Mining. At the same time several committees were established for this endeavour, including a ministerial committee as well as technical and steering committees. The main reasons to invest in nuclear power instead of other energy sources are said to be the relative cheapness of nuclear power as well as the possibility to reduce greenhouse gas emissions while at the same time not having to reduce energy consumption. Currently the Sudanese government plans to introduce its first reactor with a capacity of 600MW by 2019, with a total of ten power plants being built until 2039. To reach this ambitious goal the country works closely together with the IAEA (Gaafar and Mukhlis, 2012; Karar, 2012).

3.3.2 Preparedness Index: Sudan

Legislative framework of the Sudanese nuclear power programme

To establish a comprehensive legislative framework that is in accordance with the Milestone Approach, the Sudanese government has now started to review and amend already existing laws and regulations as well as implement new legislation that was missing or not necessary before. The first law introduced to deal with ionising radiation in Sudan is the Ionizing Radiation Regulation of Use Act of the Ministry of Health in the year 1971 which regulates the use of radiation for medical treatment in the country. Another act dealing with the use of ionising radiation has been implemented by the Ministry of Science and Technology in 1996 and was subsequently determined to be the dominant act by the Ministry of Justice after it became apparent that parts of the two acts overlapped. However, neither of those acts can be seen as complete, as they are missing vital regulations to guaranteeing the execution of its functions (Osman, 2009).

Legislation to implement a national Atomic Energy Committee was implemented in 1971 and 1973 to help with both the implementation of IAEA's technical cooperation programme as well as the promotion and regulation of nuclear technology and ionisation radiation. Other laws and regulations dealing with nuclear power and radiation on the domestic level have only been implemented in the 1990s, like a series of legislation dealing with radiation safety and protection like the General Procedures for Radiation Protection of the year 1996 or the Basic Requirements for Radiation Protection and Dose Limits of the same year. Despite having established policies for utilising ionising radiation for medical treatment in the 1970s already, comprehensive frameworks for this field and the protection of personnel and patients have only been implemented in 1998 with the Code of Practice for Protection in Nuclear Medicine Department and similar regulations. Further legislation on radiography and teletherapy only exist as drafts at the moment (ibid.).

Efforts to devise and implement a comprehensive law on nuclear power have started together with the government's plan to introduce a nuclear power programme in Sudan. In 2007 the Sudan Atomic Energy Commission established a committee tasked with drafting the so-called Nuclear Law. This act is supposed to overrule and repeal all other regulations and laws that might be contradictory while as the same regulating any use of ionising radiation including for nuclear energy generation. It furthermore stipulates the introduction of a national Nuclear Regulatory Authority for Radiation Protection made up by a technical office and a council, detailing also its responsibilities. A draft of the law had been sent to the IAEA in 2008 and was subsequently revised according to the recommendations of the agency. The Ministry of Justice ever since ruled that the law was now in accordance with national legislation and was in its final phase for approval in 2013 (Osman, 2009; Eltayeb, 2013).

The Sudanese government is party to a number of international treaties and conventions on nuclear power and radiation. Sudan is a party to the Non-Proliferation Treaty, having ratified it at the end of 1968 (Defense Treaty Inspection Readiness Program, 2009). While Sudan has also signed the African Nuclear-Weapon-Free Zone Treaty in 1996, which has come into force ever since, it has not been ratified by the domestic authorities yet. Generally, it can be said that those international treaties pertaining to nuclear matters that Sudan has already signed and ratified have been taken into consideration when drafting the Nuclear Law. However, there are still several laws to ensure a safe and secure implementation of a nuclear programme can take place that need to be joined, which is also highly recommended by the IAEA and the advisory body for Sudan's nuclear plan. These suggestions have reached the national legislative system in 2012, as the country's government is committed to become an abiding member to the international safety regime (Gaafar and Mukhlis, 2012).

At the moment the Sudanese legislative system is not yet fully prepared for the introduction of a nuclear power programme. In the past, different legislative acts overlapped or contradicted each other, some areas of nuclear utilisation for industrial or medical processes only having been addressed in the 1990s. The drafting of the Nuclear Law and the subsequent reviewing by the IAEA helped rectify these shortcomings; however, the law still has not been implemented. Furthermore, despite being member of a few international instruments for nuclear safety, there is still a considerable amount of treaties that the country should sign in order to foster confidence in Sudan's nuclear power programme, declaring that it is for peaceful uses only and adheres to international security and safety standards. Sudan is on the right path to implement a comprehensive legislative framework that addresses all the issues for the use of ionising radiation of any kind on domestic soil and corrects the overlaps and contradictions of the past. If it continues following the IAEA's recommendation, this target will be reached in time. As the country has taken several steps already to implement a comprehensive legislative framework but has not completely reached this state, it will be awarded ten of the possible 25 points for this category.

Regulatory framework

The first regulatory body that had been established was the Sudan Atomic Energy Committee that was tasked with co-ordinating nuclear energy matters between the IAEA and the Sudanese government. The Atomic Energy Committee Act of 1973 put the committee under the supervision of the National Research Council. Its task was to promote the utilisation of nuclear techniques in the country while at the same time also overseeing these activities. In 1996 the Sudan Atomic Energy Commission (SAEC) Act was passed, which incorporated the functions of both the Atomic Energy Committee as well as the Atomic Energy Research Institute (established in 1991). It is now the regulatory authority tasked with promoting the national interests of the Sudanese government pertaining to nuclear matters on both the national and international scale, being committed to helping the country succeed in implementing its nuclear power programme for peaceful purposes, while keeping the Sudanese people and environment safe from negative effects of ionising radiation. For this, SAEC is given a number of regulatory powers, including but not limited to: the establishment of infrastructure and facilities to conduct research; the training of staff and personnel in all fields concerning nuclear research and power; the oversight of environmental monitoring and radiation protection; and utilising aid from IAEA and other international organisations[4] (Sudan Atomic Energy Commission, 2008a).

Furthermore, for the protection of human, animal and plant life the Radiation Protection Technical Committee (RPTC) had been established under SAEC. Consisting of eleven members including representatives of the Ministry of Health, the Ministry of Energy and Mining, and other radiation users, the RPTC's missions was "*[t]o provide an effective regulatory services for the protection of people, property and environment at large from any radiation damage and the safety and security of radioactive materials*" (Sudan Atomic Energy Commission, 2008b). In 2010 the committee was upgraded by the Ministry of Science and Technology to be the Sudanese Nuclear & Radiological Regulatory Authority (SNRRA). It is now an entity separate from SAEC, constituting the competent authority for radiation protection and the security and safety of nuclear material in the country. SNRRA can be considered semi-autonomous, and it works closely together with the Ministry of Energy and Mining, SAEC and other stakeholders (Eltayeb, 2013; Gaafar and Mukhlis, 2012).

While it is only one of the several ministries involved in Sudan's nuclear power programme, the Ministry of Electricity and Mining plays a key supervisory role. It has been designated as the Nuclear Energy Programme Implementing Organisation (NEPIO) and will furthermore be the owner of the first nuclear reactor that is supposed to start operation in 2019. It has also started working on the recruitment and training of qualified staff and personnel for dealing with radiation protection, nuclear reactor maintenance and safety. Other ministries that are engaged in the nuclear power programme are the Ministry of Science and Technology, the Ministry of Environment, as well as the Ministry of Health, which mainly deals with the utilisation of ionising radiation for health treatment purposes, however (Karar, 2012).

[4] For a full list of SAEC's power see: Sudan Atomic Energy Commission (2008a): Historical Background. Sudan Atomic Energy Commission. [Online]http://www.saec.gov.sd/About_us.html – accessed: June 1, 2014.

What is still lacking is the an autonomous National Nuclear and Radiological Regulator (NNRR), which will be tasked with preparing and implementing all regulations and codes that are necessary for management of nuclear activities and the adherence to international quality and safety standards. This necessity has been addressed in the draft of the Nuclear Law which asks for the establishment of such a legally capacitated authority (Karar, 2012).

Similar to the legislative framework, Sudan's regulatory framework for the introduction of a domestic nuclear power programme is not yet fully developed. At present there are regulatory authorities tasked with dealing with nuclear matters and the devising of regulations and codes needed for a safe and secure construction of nuclear reactors, however real independence from the government is not guaranteed yet. The need for an autonomous authority has been acknowledge by the Nuclear Act, its implementation still has not been arranged yet, however. Furthermore, the current regulatory bodies do not fulfil their tasks to full satisfaction yet, which became apparent when the National Emergency Committee, which was established in 2007 under the Ministry of Science and Technology, failed to devise a National Radiation Emergency Plan as it never convened any meetings (Osman et al., 2009). Sudan has taken the first steps to implement a comprehensive regulatory framework for its nuclear programme, the Nuclear Act highlighting the measures that need to be taken to adhere to IAEA standards and recommendations. At the moment these cannot be met yet, which is why the country will be awarded ten points out of 25 for this category, as there is still a lot of work to be done, above all the establishment of an independent authority.

Site selection

Site selection for the nuclear power plant and supporting facilities has been on the agenda of Sudan's government ever since embarking on its nuclear journey. As the country plans on generating an additional 3400-4400 MW from nuclear power in the future, several locations for the reactors as well as facilities for spent fuel and waste storage will be needed. For this reason the Sudanese government called in help from an IAEA team tasked with finding possible sites. Following the IAEA standards for siting, the main criteria for a suitable site are: geology including seismology, volcanic activities and tectonics, ability of local infrastructure, heat removal capacity (which describes water availability), environmental and radiation aspects, as well as transportation route and public approval (Elhag, 2010).

Sudan can generally be described as exhibiting comparatively low seismic activity. Despite being struck by an earthquake of the magnitude of 7.1-7.4 in 1990, this was in the region of Juba, which now belongs to the country South Sudan. Nevertheless, other, less strong earthquakes with a magnitude around five have been recorded in the country in the past, having impact on the area around the capital Khartoum or the coast of the Red Sea, which needs to be taken into consideration when looking for a suitable site for the country's nuclear reactors. It is thus of vital importance to define a maximum acceptable level of seismic activity, as it also reflects on reactor construction and safety measures (Alhassan et al., 2007).

While the climate of Sudan varies across the regions, vast parts of the country are generally dry and arid, with rainfall only increasing further to the south. This not only has consequences for agriculture in the country, it also limits potential sites for nuclear power plants, as cooling water is absolutely necessary. A potential site is only vial if it has a sufficient amount of water in its vicinity and does not exhibit unpredictable water level changes even in Sudan's dry seasons. Because of this only the main rivers (Main Nile, Blue Nile, White Nile) as well as the coast of the Red Sea can be identified as possible areas for the construction of nuclear reactors. However, special security measures have to be taken into consideration to avoid contamination of those important water sources, which could have devastating effects on human health and the environment (Elhag, 2010).

Further issues for considerations that have been addressed by the government and the IAEA are the proximity to the electricity grid as well as public acceptance. Sudan's electricity grid, as will be discussed in more detail further down in this study, is still not universally developed. The government plans not to spend more than ten percent of construction costs for its nuclear reactor(s) on building a transmission line between the plant and the grid. Furthermore, possible difficulties in getting permission for the transmission line have been taken into consideration as well. As for public acceptance, the country has experienced strong opposition to building infrastructure for electricity generation in the past, especially when it came to large-scale hydropower projects. Public information campaigns will be necessary to gain public acceptance as will communication with Sudan's neighbours, especially those with which the country shares its water sources (ibid.).

Taking all these issues into consideration, a first general survey identified four possible regions for the construction of the country's first nuclear power plant: the Western Butana region, Southern Kordofan, the Kosti-Sinar region, or along the Red Sea. Subsequently, more detailed site selection surveys were carried out, this time by the Ministry of Energy and Mining in co-operation with an international consultant company, which identified nine potential site that are in accordance with IAEA siting standards. The third phase of siting activities has commenced since, and will be conducted by an overseas contractor with the goal of finding a final site to eventually commence construction (Gaafar and Mukhlis, 2012).

So far the siting efforts for Sudan have been mainly concentrated on finding a suitable site for the nuclear reactors themselves. However, waste management and storage facilities have been taken into consideration as well. The country started its nuclear waste management programme for wastes from medical treatment and industrial processes in 1995, for which Department of Radiation Protection and Environmental Monitoring (DRPEM) of SAEC is responsible. The first facility for this purpose was established in 2000 in Soba and "*consists of a laboratory for waste treatment, a cementation area and a storage area for conditioned and unconditioned spent/disused SRS*" (International Atomic Energy Agency, 2005b; Sudan Atomic Energy Commission, 2008c). Should the country choose to implement off-site treatment and storage facilities for nuclear waste, further considerations will have to be taken before the operation of the plant commences, as the facility in Soba is not aimed at high-level waste.

At present, Sudan's nuclear power programme is still in the site selection stage. However, in cooperation with the IAEA and international consultant agencies several site surveys have already been conducted, limiting potential areas and sites to a selected few. At the moment another survey is being conducted with the aim of finding the most suitable site that eventually will be selected for the construction of the country's first reactor. As these activities are in accordance to IAEA standards, Sudan will be awarded 15 points for this category.

Management issues

The main authorities tasked with the introduction of Sudan's nuclear power programme have already been listed above. At present, the main regulatory bodies are the Ministry of Energy and Mining (MEM), the Sudan Atomic Energy Commission, as well as the newly-established Sudanese Nuclear & Radiological Regulatory Authority. It is these that have been advancing the government's plans so far. Another important organisation is the National Electricity Corporation of Sudan (NEC), the state-owned power utility which is responsible for generation of electricity, as well as its transmission and distribution. All these regulatory bodies are active in human resource development, following the MEM's plan for educating and training enough Sudanese personnel and students to operate its nuclear programme in the future (Habbani, 2010).

Seeing as the Sudanese government has no previous experience with nuclear power for energy generation, it will most likely decide on getting a super-turnkey reactor, probably a PRW, which comes with all services to run the plant for the first few years. This, however, means that the participation of the national industry, engineers and even scientists will be considerably limited in the beginning, with in the best case only construction material like cement and experienced workers from other power generation plants being obtained nationally. For nuclear specialists and nuclear power plant personnel the right education and training courses have first to be established, for which the Ministry of Science and Technology together with SAEC has already started co-operation with international organisations like the IAEA to guarantee sufficient expertise of their human resources in the future (Gaffar and Mukhis, 2012).

The Sudanese government furthermore decided to incorporate an open nuclear fuel cycle for its first reactors, meaning that spent fuel will not be reprocessed either in domestic or foreign reprocessing plants, which strengthens the international community's confidence that no proliferation is going to take place in the country. Sudan has no experience with front end nuclear technology, making its nuclear power programme dependent on fuel supply from outside, either from the power plant suppliers themselves, which is usually done for the first four years of the reactor's operation if the contract is not prolonged, or from the open fuel market where pre-assembled fuel rods can be purchased. It is generally recommended that countries develop their own front end capacities to the highest extent as possible, as it also provides a positive stimulus for the national economy and industry. For a country starting to embark on a nuclear programme which is also one of the less developed countries in the region such an endeavour might prove to be very difficult in the beginning, however. On the other hand, contracts with international suppliers make Sudan dependent on international services, which might prove critical if disruptions occur and the reactor has to be shut down as it lacks fuel supply (ibid.).

On the back end of the nuclear fuel cycle Sudan depicts a similar lack of technologies and mechanisms to deal with nuclear waste. As already mentioned above, the domestic nuclear waste treatment plant at Soba is not equipped for the handling and storage of spent fuel and other high-level nuclear wastes. The government has thus decided on employing an open fuel cycle, which includes returning spent fuel to the suppliers, ridding itself of the responsibilities of having to find treatment and final storage facilities. Nevertheless, facilities for cooling nuclear waste, i.e. on-site water pools, and interim storage possibilities will still have to be considered. These issues will have to be given more attention in the government's nuclear plans, especially from a legislative and regulatory angle, seeing as Sudan so far has no provisions dealing with the transport of nuclear wastes to other countries. Should the government decide on transporting spent fuel and other wastes back to its supplier country not via its Red Sea port, treaties with its neighbours pertaining to these issues will have to be devised (ibid.). The decision of returning spent fuel to the suppliers is an obvious one for a country newly embarking on a nuclear programme. However, as with the front end of the fuel cycle, this leads to a dependency on foreign services, which in the worst case scenario could lead to Sudan not being able to send its wastes abroad anymore, overextending the country's interim storage capacities without any way to eventually dispose of it. For this reason it is important that the government takes long-term and final storage into consideration before or shortly after the operation of the first reactor commenced.

At present Sudan's management structure of the nuclear power programme is still not fully developed, with some authorities sharing overlapping functions (especially in the field of human resource development) and other regulatory bodies which are recommended by the IAEA not having been established yet. The programme is still in its infancy, and to guarantee a smooth implementation and operation of Sudan's first nuclear power plant, the government together with SAEC and other authorities will have to sort out responsibilities and implement the necessary regulations to ensure that a comprehensive and functional framework is in place by the time reactor construction starts. Of utmost importance is the implementation of an autonomous body to supervise all tasks, which so far has not been established. Similarly, the fuel cycle will have to be given more consideration by the government. So far the Sudanese authorities have decided on the easier option of purchasing all front and back end services, as it currently lacks the technologies and expertise to conduct those itself. However, this is not only costly, it also makes the country dependent on outside help, which is detrimental to the safe and secure operation of a nuclear power programme. Furthermore, the ability to provide these services within the country could considerably strengthen the national industry and expertise of the population, if the government manages to boost higher education to that effect.

In summary it can be said that the Sudanese nuclear power programme at present still lacks some of the necessary structures for its introduction and management as well as the capabilities to deal with the nuclear fuel cycle without having to rely on foreign help. As the owner of the plant as well as the reactor type have already been decided, the country will be 15 points for this category.

3.3.3 Sustainability Index: Sudan

Gross Domestic Product and Human Development Index

As a country having been affected by protracted civil war including the secession of a resource rich part of the country in 2011, Sudan is a relatively poor and poorly developed country. It falls into the category of low middle income countries and had a GDP of USD 58.77 billion in 2012, which had decreased in comparison to the previous year. Of its population of 35.5 million, a staggering 46.5 percent lived at or below the national poverty line. Life expectancy is currently at 62 years and slowly increasing, as is the population with a growth rate of 1.78 percent a year, which is lower than those of most of its neighbours, excluding Egypt. While the country's GDP has felt the secession of South Sudan in 2011, GDP per capita has constantly been rising the last decade and was approximately USD 3,300 in 2012 (CIA World Factbook, 2014b; The World Bank, 2014b).

When it comes to the Human Development Index, Sudan was ranked 171 of 186 analysed states, putting the country in the low development category. Its overall score was 0.411, putting it in the lower half of that category making it one of the least developed countries in the world, ranking behind all the other Arab nations. While the country saw considerable increases in its development since the introduction of the index in 1990, at which time it scored but 0.301 points, the secession of South Sudan hit the Sudanese development prospects quite hard, decreasing its score again after 2011. Furthermore, compared to other low developed countries, Sudan's improvements are relatively slow, even losing three ranks in the period between 2007 and 2012. Sudan scores lowest when it comes to education, with its mean year of schooling 3.1 years and its expected years of schooling 4.5 years. The percentage of the population receiving at least secondary education is low, with only 12.8 percent of females and 18.2 percent of all males getting more than primary education. 71 percent of the population receive primary education. The literacy rate is 73 percent, which is higher than in many other countries in the lower half of the low development category. Gross National Income in 2012 adjusted for purchasing power parity of 2005 was USD 1,848, which sets Sudan apart from other least developed country, putting it together with nations like Yemen, Lesotho or Myanmar, which all have an HDI of more than 0.45. What also distinguishes the country from other low developed countries is it comparatively high life expectancy of 61.8 years in 2012. Despite the setbacks of the last years, Sudan still experiences a continuous HDI growth of more than one percent a year (United Nations Development Programme, 2013; Sudan Tribune, 2013).

While Sudan sees slow progress in its human development, the country nevertheless ranks low in the international ranking, being plagued especially by low rates of education and a high gender inequality index even for other Arab nations, despite being ahead of countries like Saudi Arabia and Yemen in this category (Sudan Tribune, 2013). Because of its low GDI per capita and its low level of development, which both have negative consequences for the capability to sustain a nuclear power programme, Sudan will only be given one and 1.5 points respectively. In total this means the country will be awarded 2.5 of a maximum of ten points.

Economic development and quality of infrastructure

Despite being one of the least developed countries according to the Human Development Report, the Sudanese economy boomed in the last decade. This trend was mainly driven by the export of crude oil since 1999. In 2008 oil generated nearly sixty percent of all the revenues the government earned from exports, ahead of agricultural products which constitute the remainder of the country's exports. However, the secession of South Sudan, in which most of the active oil fields in the country were located (it is assumed that far bigger reserves are located in the northwest; they have yet to be made commercially viable, though), hit the fragile Sudanese economy hard. Furthermore, the country is also subject to US sanctions, limiting its trading partners considerably (CIA World Factbook, 2014c; South Sudan-American Friendship and Trade Association, 2011).

Eighty percent of the workforce is employed in the agricultural sector. Over a third of the country's area is suitable for agriculture; irrigation farming being the most common method. Sudanese farmers grow a series of crops for export, including cotton, peanuts, dates, mangoes, coffee, and sesame, together with different subsistence crops. Despite exporting a considerable amount of its produce, the country nevertheless generated an agricultural trade deficit in 2001, which could only be compensated for by its oil exports. Next to cotton, the main agricultural export is gum Arabic, for which the country produces up eighty percent of the global output. Despite being the main source of employment for the Sudanese population, agriculture is only responsible for 27.7 percent of the country's GDP, with industry and services generating 33.6 percent and 39 percent respectively in 2013. However, the industry employs only seven percent of Sudan's workforce, the service sector only 13 percent (CIA World Factbook, 2014c; Advameg, Inc, 2014).

Sudan's economy suffers from a series of negative factors: in 2011, after the secession of South Sudan, a new currency was introduced by the government (keeping its old name, Sudanese pound), which immediately faced devaluation and inflation. At the end of 2012 inflation had reached 47 percent, and while it had decreased to 25 percent in 2013, it is still high. Furthermore, the country's unemployment rate is at twenty percent and nearly 47 percent of the population lived below the poverty line in 2009[5]. With the loss of most of its oil revenues, the Sudanese government is once more faced with a trade deficit as well (CIA World Factbook, 2014c).

At present, Sudan's GDP increased by 3.6 percent in the year 2013, a growth that was mainly driven by agricultural exports as well as mining of gold, together with revenues from oil exports and the Transitional Financial Arrangement (TFA) that has been concluded with South Sudan. The economic situation is still instable, however, being intensified even more by the sensitive situation within the country, caused by the situation in Darfur as well as frequently occurring riots. While the Sudanese government works closely together with the United Nations Industrial Development Organisation (UNIDO), more efforts are required to stabilise and strengthen the domestic economy (Yousif et al., 2014).

Sudan's infrastructure is in a similar situation, being at a relatively low level of development and quality. In the Logistics Performance Index of the World Bank the country ranks near the bottom in terms of "*quality of trade and transport-related infrastructure*", seeing, however, considerable improvements in the time span of 2009 to 2013 compared to the years before. In 2013 the infrastructure quality scored 2.01 out of five, depicting a steady improvement (The World Bank, 2014c).

Sudan's transportation infrastructure is only unevenly developed throughout the country. In parts there are no paved roads at all, leaving villages completely unconnected to other regions. Roads and railways are generally concentrated to the main cities, most of all Khartoum, and corridors interconnecting them. The best developed route is between the capital and Port Sudan at the Red Sea, on which the highest traffic volume can be found. Even on other important corridors, for example one connecting the country with the Ethiopian capital Addis Ababa and the Port of Djibouti is not that well maintained in comparison. In total, Sudan possessed around 4,000km simple-track railroads and close to 2,000km paved roads, which is considerably little for a country of Sudan's size. Furthermore, only 26 percent of the anyway insufficiently developed transportation network are in good condition. This low quality

[5] This figure still includes South Sudan as no newer data is available yet.

transportation infrastructure has negative effects, above all the high freight-costs, which are around twice as high as on other continents, and the inhibition of business activity. The country's main port is Port Sudan and even there activities are limited because of long port and clearing times (Ranganathan and Briceño-Garmendia, 2011).

Sudan's electricity and water/sanitation infrastructure is similarly developed. The national grid consists of a total of 63,719km of power lines, owned by the state-run utility National Electricity Corporation of Sudan. The sector is characterised by frequent power outages due to low investment in infrastructure during the years of civil strife. Furthermore, rural access to electricity is still very low, with about seventy percent of it being consumed in the greater-Khartoum area. In total, only thirty percent of the population had access to electricity and those are connected via the two national grids, the Western grid and the Blue Nile grid. The rest of the population needs to rely on diesel generators for electricity (MBendi, 2014; Lucy Switchgear, 2014). For the introduction of a nuclear power plant it is of utmost importance that the government enhances and stabilises the national grid to allow safe transmission of the electricity generated by the reactors, while at the same time taking safety aspects into considerations.

Water supply and sanitation pose a similar challenge to the Sudanese government as only 15 percent of the population has access to utility water, constituting a sharp decline as in 1993 close to sixty percent could rely on that kind of access to clean water. While in Khartoum and other big cities about forty percent could access utility water, in rural areas seventy percent have to rely on wells and boreholes. As for sanitation, "*close to forty percent of the population has access to improved latrines*" (Ranganathan and Briceño-Garmendia, 2011). Flush toilets, however, are only utilised by 14 percent of the urban and one percent of the rural population (ibid.). Especially the decline in access to utility water shows the precarious state of the national water infrastructure, which needs to be improved not only for the sake of an increase of quality of life for the Sudanese population, but also since the availability of a functioning cooling water system is absolutely necessary for the secure operation of a nuclear power plant.

Compared to the other parts of its infrastructure, the Sudanese telecommunication and information infrastructure scores high and can be seen as on par with other African countries. GSM coverage can be found in close to eighty percent of the country, and mobile telephony usage has been growing rapidly, reaching 33 percent in 2009. On the other hand, landline service supply grows only slowly. As for internet penetration, the sector also grows at a fast rate, though it is still lagging behind more affluent African nations. Low prices both for internet as well as mobile phone access are a big advantage for the Sudanese people, stimulating business activities in this sector at the same time (Ranganathan and Briceño-Garmendia, 2011).

In summary it can be said that Sudan's economy and quality of infrastructure are not favourable for the implementation of a nuclear power programme. The economy, despite exhibiting continuous growth rates the last years, continues to be unstable, having still not fully recovered from its loss of oil revenue in 2011. Furthermore, the majority of the Sudanese people is still working in agriculture, which limits the possibility of finding national employees for the power plant's construction and operation. The situation of Sudan's infrastructure is similar. Apart from the ICT sector, which has been developing considerably the last years, the country's infrastructure is in a very poor shape, which mostly only people in urban areas have access to. For the introduction of a nuclear power programme a more developed and stable infrastructure, especially for transportation and electricity, is needed. In consideration of these facts Sudan will be awarded with ten points out of thirty for this category, as large-scale improvements of its infrastructure and economy will be needed to guarantee as safe and secure operation of its future nuclear reactors.

Industrial development

Despite being endowed with a number of natural resources like crude oil, minerals and agricultural produce, Sudan's industrial development has been slow. While the country has lost its major oil fields with South Sudan's secession in 2011, it is now exploring, together with investors from Asia, mainly China, the development of new fields in other parts of the country. In 2010 oil contributed to close to 75 percent of the country's exports, which is mostly trading with partners like the People's Republic of China as it is still burdened with economic sanctions from the United States (Economy Watch, 2010).

Next to crude oil drilling and refinery activities, important activities of the Sudanese industry are sugar refining, cotton ginning and the textile industry, which the government actively seeks to promote. The mining industry, in comparison, is only insufficiently developed, despite the assumption that Sudan has an abundance of natural resources that are sought after on the world market. In recent years the government has tried to develop more capabilities in these sectors, however, implementing the first gold refinery in the country in 2012 (CIA World Factbook, 2014c; Economy Watch, 2010; BBC News, 2012).

Sudan's industrial development has been slow in the past. However, it picked up its pace, generating an industrial production growth rate of eleven percent in 2013 (CIA World Factbook, 2014c). Nevertheless, while it is certainly a positive development for the country, the implementation of industries that could support a nuclear power programme with domestically produced parts and experts has still not been given enough consideration, making the country insufficiently prepared for the operation and maintenance a nuclear reactor in this regard. Thus, Sudan will be given five out of a maximum of twenty points in this category. However, a first positive step would be the upgrading of the already existing industry like the cement sector to be able to adhere to international quality standards so that at least these industries can contribute to the nuclear power programme until more advanced ones have been developed and implemented in the country.

Financing

In light of its comparatively low level of (economic and industrial) development, Sudan will not be able to finance its nuclear power programme itself. Not only is the construction of a nuclear power plant costly (USD 5-6 billion, not including the financing and funding that is needed for maintenance), the country will furthermore have to make a series of infrastructural upgrades to accommodate the project in the first place. For the Sudanese government this poses a challenge that cannot be solved without outside help, which is both acknowledged by then domestic authorities itself as well as the IAEA and international consultant firms working together with the government on this programme (Gaafar and Mukhlis, 2012).

The secession of South Sudan resulted in a budget deficit for the North as oil revenues plummeted and the economy lost its driving force. Despite the introduction of reforms intended to stimulate other economic sectors, real GDP growth for those sectors was only 4.6 percent in 2012, with inflation eating away these small gains. The budget deficit in the same year was 3.8 percent, while the external current account deficit had increased to more than ten percent. However, grants and loans from international donors had increased since South Sudan's independence. While the Sudanese government with the help of experts like the International Monetary Fund (IMF) tries its best to achieve macroeconomic stability, economic growth apart from oil-related developments is expected to slow down even further. In addition to that, the IMF points out that Sudan's debt distress and the ever-growing volume of arrears make it difficult for the country to receive more external financing (International Monetary Fund, 2013).

This precarious financial situation is not favourable for Sudan's domestic nuclear power programme. It makes the country dependent on international loans and financing help, and these financing schemes do not include preparation for the eventual decommissioning of the reactor or financial preparedness for emergencies and other, smaller, accidents.

In the past, Sudan already worked together with entities like the World Bank or the Islamic Development Bank (IsDB) to receive financing for the extension of its electricity grid. Together with the IsDB the country implemented two projects between the year 1999 and 2011. As was pointed out in the course of these projects, the state of the utility was bad because of a lack of investment, which again indicates financial constraints of the government (Islamic Development Bank, 2012).

Thus, even if Sudan gets the necessary financial support from the international community to build its first nuclear power plants, the country will be dependent on continuous backing to maintain and sustain the reactors, unless its economy experiences an unforeseen growth within the next few years which could alleviate the country's financial burden. Generally speaking it can be said, however, that from a financial standpoint the country is not fit to introduce nuclear power, as not only the costs of the plant and its maintenance itself have to be taken into consideration, but also the necessary infrastructure upgrades, costs for waste storage and disposal, as well as the eventual decommissioning. Furthermore, as the electricity grid at present only reaches a small share of the population, a possible taxing scheme to fund future projects (like the decommissioning) is hardly feasible at the moment. In light of these shortcomings, Sudan will be awarded only five out of a maximum of twenty points for this category.

Human resource development and education

The Sudanese educational system has been expanding progressively in the last years, despite this progress being slowed down by ongoing civil strife. Until the first half of the 1990s, Sudan's educational development lagged behind the other categories of the Human Development Index, which were already developed higher and also improved at faster rates. Only in 1995 education picked up speed, having now made a greater progress than the income index of the HDR (United Nations Development Programme, 2012). The government has made education compulsory between ages six to 13, while at the same time providing it for free. The educational system follows the 6-3-3 system which has been implemented in the 1990s. Nevertheless, Sudan's education faces several severe problems. First of all, many educational progresses were undone by social instability caused by the ongoing civil wars. Secondly, the drop-out rate from primary schools is comparatively high with 9.1 percent, with this figure being much higher in conflict-stricken areas. As already mentioned above, the mean year of schooling in Sudan is 3.1 years and expected years of schooling 4.5 years. Only 12.8 percent of women and 18.2 percent of men have at least secondary education, which shows that the level of education is generally very low in the country, with drop-out rates from secondary schools being even higher than for primary schools. Enrolment rates for secondary schools were at only around forty percent in the period from 2002 to 2011, rates of university students even lower with 6.1 percent in the same time span. What exacerbates the problem even further is the fact that only close to sixty percent of all primary teachers possess a teacher's licence, which is reflected in the fact that only 43 percent of the population is satisfied with the quality of education in the country. In comparison to other Sub-Saharan African countries, Sudan's adult literacy rate is relatively high with 71.1 percent (United Nations Development Programme, 2013).

At present, Sudan operates thirty governmental universities (including religious schools and colleges) as well as around 54 private colleges and universities, and a number of technical colleges which are now under the National Council for Technical and Technological Education (Ministry of Higher Education and Scientific Research, 2014). A cornerstone of Sudan's technical education is the Sudan University of Science and Technology, which is composed of 19 colleges on nine campuses in the area of Khartoum. In 2009, it had 24,000 undergraduate students pursuing a Bachelor of Science degree, 31,000 getting a diploma, and 5,000 postgraduate enrolments. The university offers a variety of degrees in fields like technology, science, and engineering, even having its own department for medical radiological science, which is essential for the safe application of ionising radiation in health care facilities (Sudan University of Science and Technology, 2014).

Adequately trained personnel and staff are one of the potential problem areas the Sudanese government has highlighted together with the IAEA. As the Nuclear Law has not been put into force yet, regulative authority to oversee the implementation of human capacity building programmes has not been given to one overarching body yet. At present, different organisations are involved in the education of training of future experts. For this reasons the Sudanese authorities have implemented the so-called Human Resource Development Master Plan to involve all the parties concerned in the effort to promote higher education and the training of specialists in nuclear matters. First of all, there are the universities, which offer both undergraduate and graduate degrees in natural sciences, technology, and engineering. They are managed by the Ministry of Higher Education and Research. The Sudanese government has already started to introduce curricula for degrees directly related to a nuclear power programme like nuclear physics and engineering, nuclear science and technology, as well as medical physic, the latter two Master degrees being offered at the Sudan Academy of Science. This, together with a growing number of graduate students in these subjects, indicates a positive development and shows that the government intends to nurture and subsequently use its own people for the construction and operation of its reactors. In the academic year from 2007-2008 close to 44,000 students were registered for the different degrees in natural sciences and engineering, and it can be assumed that this figure has further risen ever since. At present, around thirty people graduate from the department of Nuclear Engineering each year, constituting a potential source of professionals that can be employed for the operation of the first reactor (Eltayeb, 2013; Karar, 2012).

Further specialists will be recruited with the help of SEAC, which will also transfer part of its specialists to the programme, as well as from the five companies active in different fields of electricity generation owned by the MED. Some of their stuff will also be available for the start of the first reactor's operation. The Sudanese Atomic Energy Commission employed around 190 trained technologists and researchers in 2013, which will be tasked with vocational training courses to ensure that enough qualified personnel is available for the nuclear power programme. These activities are done in co-operation with the IAEA, which supports the local trainers and oversees the adherence to quality standards. Furthermore, the SAEC also runs a Non-Destructive Testing (NDT) training centre and is now planning to construct research reactors for further studies and staff training. However, while SAEC's staff is highly educated and adequately trained in nuclear matters, its numbers are low, seeing as in 2010 only 12 scientists with a PhD and 51 with a Master degree were employed there. For an ambitious nuclear power programme like Sudan's this number will have to be raised to not suffer from a shortage of qualified personnel (Eltayeb, 2013; Karar, 2012).

For the staffing of regulatory positions, the Sudanese Nuclear and Radiological Regulatory Authority is responsible at the moment. It follows a multi-disciplinary approach and employs around thirty regulators at present. While plans for local training in necessary regulatory functions are devised for the future, at the moment training is provided by the IAEA and other international organisations like the Forum of Nuclear Regulatory Bodies in Africa (FNRBA) (Eltayeb, 2013).

A further stakeholder in Sudan's human resource development for its nuclear power programme is the National Electricity Corporation, which operates a Regional Training Centre with comprehensive training programmes, as well as a general directorate tasked with human resource development and training. In 2010 it employed around 1,150 engineers, 701 people managerial staff and 16 programmers (Eltayeb, 2013).

From the analysis of Sudan's educational system and human resource development it became apparent that the country suffers from a discrepancy. On one hand, the general education of the local population is comparatively low. While the literacy rate is high when comparing it with other Sub-Saharan countries, only a small percentage of the Sudanese people receive secondary or higher education. Drop-out rates are high, even for primary schools, despite compulsory education until age 13. Furthermore, the quality of education has been judged to be relatively poor, which is also reflected in the number of primary teachers that have received teacher's training. On the other hand, Sudan has a high number of universities and other facilities of tertiary education, having already implemented a number of programmes for the training of reactor personnel and nuclear scientists. The Sudanese government also works closely together with the IAEA and other international organisations to ensure that the nuclear power programme can be operated by local specialists in the future. At present, the number of scientists with at least a Master degree is still relatively low and will have to be increased in the future. Nevertheless, it is absolutely necessary that Sudan's general education will be improved, not only as education helps bring the people out of poverty and alleviate gender inequality, but to also ensure that enough qualified staff is available for the nuclear power programme in the future. Sudan's higher education has implemented several measures to accommodate the needs of the government's nuclear ambitions. As the general education system still needs to be improved, however, the country will only be awarded ten out of twenty points for this category.

3.3.4 Emergency Preparedness Index: Sudan

Political Stability

Sudan is one of the most unstable countries in the world and scores the third rank in the Fund for Peace's Failed State Index, only being surpassed by war-stricken Somalia and the Democratic Republic of the Congo. The country scored a total of 111 points out of 120, highlighting the precarious situation the country is in. The best results Sudan received in the category of "Poverty, Sharp or Severe Economic Decline", where it was awarded "only" 7.3 of ten points, whereas in all the other categories it scored more than 8.4 points. In three out of twelve categories Sudan scored the maximum of ten points, indicating the shortcomings in these fields. Two of them are social indicators: "Group Grievance" highlights the existence of "*tension and* *violence […] between groups*", which undermines "*the state's ability to provide security*" (Fund for Peace, 2013). In Sudan's case this means water scarcity, malnutrition, diseases, and high mortality rates. The second social category, "Refugees and IDPs", indicates problems concerning security threads, population displacement as well as the number of refugees per capita. Years of internal strife and civil war have made the country especially vulnerable to these issues. Closely linked to these two indicators is the one analysing the security apparatus, a category in which Sudan also scored the maximum points. The indicator "Factionalised Elites" describes a situation "*when local and national leaders engage in deadlock and brinksmanship for political gain, this undermines the social contract*" (Fund for Peace, 2013). In the case of Sudan this highlights flawed elections, power struggles and political competition. Furthermore, the Failed State Index of 2013 shows that the country shows severe shortcomings in terms of rule of law and human rights, the security apparatus (i.e. ongoing internal conflicts, the existence of political prisoners, as well as protests and riots), and the legitimacy of the state; in all these categories Sudan scored more than nine points. The country has been categorised as one of the most corrupt nations in the world, with the ruling party concentrating resources and power among itself, while many parts of the country are neglected and the legal framework for private property protection is hardly observed (The Heritage Foundation, 2014). A further problem threatening political stability in Sudan is terrorism. Religiously-motivated terrorist groups located in Sudan are active not only nationally but also on the international stage, threatening their own government as well as countries like the United States, France, and the United Kingdom (Sudan Tribune, 2009).

For Sudan's nuclear power programme these facts have negative implications. When constructing and operating nuclear reactors, political stability is absolutely essential to ensure security and safety of the plant. If, as is the case with Sudan, the political situation is extremely unstable and terrorist groups are actively operating within the country, an operation free of failure and troubles cannot be guaranteed. In light of the tenuous state the country is in, Sudan will be awarded zero points for this category, as with conditions like that no nuclear power programme should be introduced.

Medical infrastructure

Despite going back to 1899, the modern Sudanese health infrastructure is relatively poorly developed in comparison to other Arab Muslim countries. The country's Ministry of Health was established in 1949, and each of Sudan's 25 states has its own health authority managing the provision of medical care. While the Sudanese constitution dictates free access to primary health care, advanced facilities providing treatment are rare outside the big cities, and even in the capital quality institutions are rare. Plans to introduce a comprehensive medical system throughout the country exist since the 1970s, their implementation, however, has failed due to a lack of finances and the ongoing civil strives up to the present years (Kjeilen, 2014, World Health Organisation, 2009).

A health insurance system was established in 1996; nevertheless the number of Sudanese people having signed up for such an insurance plan is low. Also strikingly low is the number of doctors in the country, with only three specialists for every 10,000 people. As most are concentrated in cities, where they have better access to necessary equipment and furthermore receive more pay, the lack of doctors in rural areas is even more exacerbated. In 2004, all over the country only 1,400 functioning hospitals and health care centres had been established[6]. The consequences are low life expectancy and a high child mortality rate (in the region of South Kordofan more than ninety infants out of 1,000 die before their first birthday) (World Health Organisation, 2009; Our Africa, 2014).

Despite the share of the national budget being spent on health care rising up to seven percent in 2008, this figure is still below the WHO's recommendation for a functioning health care system. As up to 75 percent of all Sudanese doctors decide to leave the country and work abroad, the national government is already talking about a "health worker crisis", which could negatively impact the country's provision of health services even further (Syeed, 2014; Our Africa, 2014).

As for facilities dealing with ionising radiation applications for medical treatment, only three education and training institutes existed in the country in 2005. The IAEA helped to establish the Faculty of Radiological Sciences and Nuclear Medicine,

[6] This figure still includes facilities in the now independent South Sudan.

which is a first step to equip Sudanese facilities with technologies to both utilise as well as deal with ionising radiation (The National Ribat University, 2014; World Health Organisation, 2009).

Generally speaking, the Sudanese medical infrastructure is not yet adequately equipped for dealing with nuclear accidents and emergencies. The domestic health care system is still only poorly developed, with facilities being concentrated in cities and the number of practising doctors being very low. Even the provision of primary health care poses a challenge for the country, thus indicating that as a first step the basic medical infrastructure needs to be improved before measures to prepare hospitals and health care facilities for nuclear events and disasters of any kinds can be implemented. While a rising share of Sudan's GDP is being spent on health care and improving the existing system, with the government also working closely together with the WHO and other international health organisations, the brain-drain of trained doctors as well as the "gutting" of public hospitals since their privatisation poses a new challenge for the local medical infrastructure (Syeed, 2014). In consideration of these facts, it cannot be said that Sudan's medical system is sufficiently prepared to accommodate the introduction of a national nuclear power programme. First of all the general infrastructure will need to be improved, then specialised frameworks for handling of nuclear events will need to be devised. The country will thus only be awarded five out of a total of 25 points for this category.

Disaster Management

Sudan is a country relatively vulnerable to disasters, both natural as well as man-made ones. Its low level of development in many cases worsened the situation when a disaster hit, as the government lacked the means and organisation to actively react to the event in a fast and reliable manner. In the two decades up to 2010 Sudan[7] experienced a total of 77 man-made disasters, killing over 160,000 people, an average of 5,179 per year, and causing an economic damage of USD 526,200,000, negatively affecting the development process of the country. In total, in the years between 1980 and 2010 more than 33.5 million Sudanese people were affected by natural disasters, coming close to the country's current population (PreventionWeb, 2014).

[7] This statistic still includes South Sudan as well.

The disasters that hit Sudan the hardest in the past decades were droughts, floods and heavy rains, as well as epidemics. The droughts of 1983 and 1991 affected more than eight million people each, with the former one killing an estimated 150,000 people, becoming the worst disaster in Sudan's history when it comes to lives taken. When it comes to economic damage, however, it is floods that cause the highest financial losses for the country. Both flooding and drought events are estimated to increase due to climate change, and international organisations are thus calling for the development of an elaborate disaster management plan to tackle these issues. A further disaster that often affects the country, especially its north and centre, are dust storms. While their effect on human life is relatively limited, they nevertheless result in problems for air and land transportation (PreventionWeb, 2014; Republic of Sudan, 2007).

The main authorities in Sudan's disaster management are the Ministry of Health and the National Council for Civil Defence. The latter was established as a High Council in 1991 and has been subsequently renamed to National Council in 2005. Its head is the Minister of the Interior, who is authorised to add members to the council. The main responsibilities of the National Council for Civil Defence, as defined in Article VI of the Civil Defence Law, are: coordinating measures and policies for emergency preparedness and mitigation; assigning the roles and duties to national and international parties in case of emergency; and the approval of the council's budget. For an adequate disaster management the Sudanese government has devised two main policies: The first one being the National Emergency Policy, the second one the National Health Sector Policy for Disaster Mitigation, Preparedness and Response. The latter one was devised in 2002 and would have constituted the main framework for disaster management in the country. However, due to the ongoing conflict in Darfur, it has never been implemented, constituting a shortcoming of the national preparedness policies (Khartoum State Police, 2011; World Health Organisation, 2010).

Next to natural disasters, man-made emergencies also need the attention of Sudan's policy makers. The biggest catastrophe in that regard is the ongoing crisis in Darfur, where 1.9 million people were estimated to live as internally-displaced persons (IDPs) in 2011. In this situation, as well as in the case of the latest flood in 2013, which affected 250,000 people in 13 Sudanese states, it becomes apparent that the Sudanese government does not possess the means to adequately response to such disasters. In both cases the responsible authorities work closely together with international organisations like the WHO and the International Federation of Red Cross and Red Crescent Societies (IFRC) to provide primary crisis response and medical treatment. As the flood in 2013 showed, the country is especially dependent on financial support, having requested USD 15,000 for being able to implement its flood response plan. The damage done by the heavy rain to hospitals depicted further weaknesses in Sudan's disaster preparedness. As the incidence of flooding is expected to increase due to climate change and the deforestation of catchment areas (especially in the Ethiopian mountains), the Sudanese government will have to devise better prevention measures as well as policies for the response to such disasters in order to minimise impacts on its population and economy (World Health Organisation, 2013).

As the presence of international organisations is high, a number of programmes and plans for disaster management have already been implemented, among them the International Health Regulation, the Water Quality Control Programme, or the Communicable Disease Control Programme. However, these measures have mostly been taken in response to man-made humanitarian disasters. A comprehensive disaster management system including all three issues (prevention, response, mitigation) will still need to be implemented to allow a faster and more effective response to disasters of any kind in the future (World Health Organisation, 2010).

At present, Sudanese disaster management is still not fully developed. The country is dependent on international support both for emergency response as well as financing response and mitigation measures when a disaster has hit the country. The main regulatory bodies are the National Council for Civil Defence together with the Ministry of Health; however these two can be seen as less effective than international organisations operating in the country or agencies like the Sudanese Red Crescent Society (SRCS). While Sudan possesses a basic framework for disaster management, it still needs to be fully implemented to allow a quick and efficient response in case of emergency. However, the country is still largely dependent on financial aid to provide primary disaster response, showing another shortcoming of the present management system. As droughts and floods are expected to increase in the future disasters due to climate change, the Sudanese government will need to invest more efforts and money into mitigation measures to limit negative impacts on human health and the environment. The current management systems can be judged as insufficient in that regards. In summary, while the country possesses a basic structure for disaster management, it is not enough to sufficiently deal with national disasters. In light of these facts Sudan will be awarded five out of 25 points for this category.

Radiation management and protection

Despite utilising ionising radiation for diagnostic purposes since the 1930s and the use of radiological technology in the fields of medicine since 1965, Sudan's radiation protection activities only started in 1967. The first law concerning this issue was introduced in 1971, the Regulation of the Use of Ionising Radiation law, which established a committee tasked with granting licenses for utilising radiation for medical purposes. Another act, implemented in the 1973, established the Atomic Energy Committee, with the aim to oversee the use of radiation and other nuclear technologies to guarantee these activities' safety (Elamin, Hajmusa and Shaddad, 2001).

At this point, however, a comprehensive legislative framework for radiation protection was still lacking, and it would only be in 1996 that this issue came to be addressed. Only with the implementation of the Sudan Atomic Energy Commission Act of that year a management structure for radiation protection was devised. On the first - of a total of three - levels is the Board, which is composed of 21 members, all scientists or high-level officials. It is responsible for ensuring radiation protection and safety, especially those of humans, by regulating in which ways ionising radiation and other techniques can be applied. Furthermore, it appoints the Radiation Protection Technical Committee (later renamed the Sudanese Nuclear and Radiological Regulatory Authority) and needs to approve this committee's policies and drafts before they can be put into force (ibid.).

The second level of Sudan's regulatory framework for radiation protection is the Sudanese Nuclear and Radiological Regulatory Authority. The SNRRA consists of eleven specialists from educational facilities and institutions dealing with the protection of human life and the environment in the country from harmful effects of ionising radiation. While it needs the approval from the Board in many issues, it is nevertheless tasked with important functions. Its most important assignment is the development of policies concerning environmental monitoring and radiation protection while also framing financing schemes for these issues. Once these proposals have been approved by the Board, the SNRRA oversees the implementation of and adherence to these guidelines and regulations. Furthermore, the SNRRA is also tasked with issuing licences for facility siting and the application of practises (Elamin, Hajmusa and Shaddad, 2001).

The Implementing Technical Body is the last level of Sudan's regulatory framework for radiation protection. This body is actually the Department of Radiation Protection and Environmental Monitoring of the Sudan Atomic Energy Commission, which has been designated by the SNRRA to work for it. It is staffed with 17 technicians and scientists in fields like chemistry and physics and pursues a supervising function. The DRPEM is responsible for licence examination, the execution of inspections, as well as quality control and the establishment of an environmental monitoring programme. In addition to these functions, the DRPEM also keeps an inventory of radiation sources, the sites and facilities where these are being applied, and who the owner/operator of these is (ibid.).

To ensure the safety of humans and the environment, the Board has implemented a number of regulatory policies. One of the first such regulations is one on general procedures in terms of radiation protection, which was issued in 1966. Other important ones have only been implemented in 1996 or after, like regulations dealing with licensing procedures, the transport of radioactive material, as well as several safety guides for areas in which ionising radiation is applied (Elamin, Hajmusa and Shaddad 2001).

For radiation protection in case of a nuclear power programme, a national monitoring system is necessary. The first step in this direction has been made with the introduction of a baseline radiation map, which monitors radiation concentration throughout the country. Due to Sudan's large size and its financial constraints, at present the monitoring system is concentrated in areas which are estimated to yield comparatively high natural radiation content. By the time the plans for the first nuclear reactor are being finalised, it would be important to have expanded that system to monitor radiation levels on a nationwide scale (ibid.).

In 2004 the Radiation Safety Institute (RSI) was established under SAEC with the object of providing services for radiation protection to facilities handling radiation sources, as well as the training of radiation workers in these fields. The RSI furthermore defines acceptable concentrations for humans and the environment, while dose limits for facilities have been issued by the Board and are in agreement with international recommendations. The RSI also helps with personal monitoring and equipment testing for radiation equipment testing (Sudan Atomic Energy Commission, 2008c).

For emergency response in case of accidents with radiation and nuclear material the National Committee for Radiological Emergency Preparedness and Response, which was established in 2007, is responsible. Reporting to the National Council for Civil Defence, it is tasked with devising a domestic emergency plan for radiological accidents and the establishment of a primary response team prepared for such an accident. In addition to this basic plan, a separate one will have to be drafted by the reactor's operator/owner, which needs to take into account issues like site characteristics and location while at the same time being in accordance with the basic plan decided by the Committee (Ministry of Energy and Mining, 2009).

An important part of any emergency plan for radiological accidents is the availability of evacuation infrastructure and radiological shelters, which will need to be implemented to ensure the highest possible safety for the population in case of emergency. As already discussed as part of the Sustainability Index, the Sudanese infrastructure is poorly developed, which will also be the case for evacuation infrastructure and emergency shelters. Despite financial constraints the Sudanese government will have to allocate funds to establish necessary structures for evacuation and protection of its population.

While Sudan seems to have implemented a basic management structure for radiation protection, the country also suffers from problems in that regard. Apart from the already mentioned financial constraints, the lack of spare parts and trained personnel, which is aggravated further by brain drain of specialists, pose a challenge for the radiation management in the country. Furthermore, as became evident in the course of an incident in 2008 when an industrial radiography projector was stolen, security procedures were not sufficient nor were the emergency measures at that time (Osman et al., 2009).

In light of these facts it can be said that Sudan's radiation protection system is still not fully developed at the moment to deal with the challenges a nuclear power programme bring with it. A basic management system exists and the Sudanese authorities have been working together with the IAEA to implement a more comprehensive infrastructure in that regard. To be fully prepared for potential radiological accidents, a number of policies and measures still have to be implemented, above all a functioning evacuation infrastructure including emergency shelters to guarantee the protection of the affected population. Because of these issues that still need to be addressed, Sudan will be awarded ten out of 25 points for this category.

3.3.5 Final Score: Sudan

Table 3 Critical Powers Index: Sudan

Index	Points	Sub-index	Points	Weighting factor	Sum
Preparedness Index	50			1	50
		Laws	10		
		Regulatory authorities	10		
		Site selection	15		
		Management issues	15		
Sustainability Index	32.5			2	65
		GDP/HDI	2.5		
		Economic development/ Quality of infrastructure	10		
		Industrial development	5		
		Financing	5		
		Human resources /education	10		
Emergency Preparedness Index	20			1.5	40
		Political stability	0		
		Health care	5		
		Disaster management	5		
		Radiation protection/management	10		
					155

The above table show the overall Critical Powers Index for Sudan. With a final score of 155 points the country reaches only a third of the maximum possible points of 450 points. This means that Sudan is not adequately prepared for the introduction of a nuclear power programme and is still a long way from reaching the 270 points the author recommended in the methodical part for being the minimum allowing a country to proceed with its plans. Looking at the three different indices it becomes evident that the Sudan achieved the best results in the Preparedness Index, which measures the country's adherence to the Milestone Approach. As the IAEA is overseeing Sudan's progress in the issues dealt with in the document, it is self-evident that the Sudanese government concentrates its efforts to reach the three milestones. Furthermore, the issues addressed in the Milestone Approach are, in comparison with those presented in the other two indices, easy to solve as they mainly deal with matters related exclusively to the nuclear programme and thus do not need a lot of preliminary preparations. With the help and advice of the IAEA Sudan thus reached its best results in the fields of site selection and general management, being awarded more than half of the possible points for these categories. For the Preparedness Index as a whole, Sudan achieved fifty out of one hundred points, bringing the country close to the sixty percent that have been proposed as a minimum in the methodical part of this study.

The scores for the other two indices shine a less optimistic light on Sudan's nuclear power programme, however. Looking at the Sustainability Index, it becomes evident that Sudan is still a poorly developed country lacking both the financial means to upgrade its infrastructure and finance its own nuclear power programme. The country will be extremely dependent on international financial aid to introduce and sustain its first nuclear reactors, as its economy is struggling despite its abundance of natural resources and its industry weak. These shortcomings make it neigh impossible to operate and maintain a nuclear power plant in a safe and secure manner, as a functioning infrastructure is a prerequisite for being able to act in a timely manner in case of any event or even for the construction of the reactor in the first place. Furthermore, the poorly developed electrical grid that only supplies a fraction of the population of the country is neither prepared for receiving the electricity generated by the power plants nor for guaranteeing a steady supply for the reactor if needed. In light of these shortcomings Sudan was only awarded 65 out of 200 points for the

Sustainability Index, highlighting that the country's economic situation and infrastructure are not sufficiently prepared for the introduction of a nuclear power programme.

The issues dealt with in the Emergency Preparedness Index cast an even less favourable light on Sudan's capabilities to implement and sustain a nuclear power programme. The most dangerous fact is that Sudan is one of the most unstable countries in the world, ranking high in the Failed State Index. Internal conflicts and riots continue to be an issue even in 2014 and the rule of law cannot be guaranteed. These facts put Sudan's nuclear power programme in extreme jeopardy as the safety and security of the reactors cannot be guaranteed. Furthermore, neither the medical infrastructure nor the disaster management system are sufficiently developed, as the country continues to be dependent on international support to provide even the most basic medical services and disaster relief in conflict-stricken areas. When it comes to radiation protection and management, Sudan has worked hard to adhere to international standards in this field, trying to implement steps to guarantee radiation protection in all areas in which ionising radiation is being utilised. While the basic regulatory framework and infrastructure for this have already been implemented, the Sudanese government will nevertheless have to improve its preparedness when it comes to possible – minor as well as major – events in nuclear reactors, needing to prepare both a comprehensive emergency plan for such accidents as well as evacuation shelters for the population. Nevertheless, compared to the other issues dealt with in the Emergency Preparedness Index, Sudan possesses the basic policies and infrastructure for efficient radiation protection. Nevertheless, the country achieved only twenty percent of a total of 150 points for this index, highlighting the severe need for improvement in this field.

Adding up all three indices, Sudan reached a total of 155 of 450 points, which shows that, despite having the support of the IAEA, the country is less than prepared for the challenges a nuclear power programme pose even for the most developed countries. To successfully introduce nuclear power in the country, the ambitious plans of the government would have to be postponed to first improve political stability together with its economic capacities and infrastructure to be able to fully concentrate on the safe and secure implementation of the programme afterwards.

4. Evaluation and recommendations

4.1. Evaluation

After analysing Japan and Sudan according to the Critical Powers Index that was developed in the methodical part of this study, the author will now take these results to evaluate the two countries. The similarities and differences shall be highlighted to compile a number of recommendations for the IAEA Milestone Approach in the second part of this chapter.

Preparedness Index

Generally speaking, Japan's and Sudan's history with nuclear power is characterised by a completely different development. While Japan began developing its interest in the use of nuclear power for electricity generation already in the 1960s and subsequently constructed its first reactor without foreign help in 1966, Sudan's interest in nuclear techniques remained limited until the 1990s (Osman, 2009; International Atomic Energy Agency, 2011). This divergent development lead to Japan possessing 54 reactors in 2010, while Sudan only started formulating plans for the introduction of nuclear power in 2007 (World Nuclear Association, 2014; Gaafar and Mukhlis, 2012). In light of these facts it is not surprising that the Japanese government has developed a highly comprehensive and overarching legislative framework to deal with nuclear issues as well as a wide-ranging regulatory system that has been reviewed and overhauled in the aftermath of the Fukushima incident as certain shortcomings became apparent.

Japan's legal framework is built around the Atomic Energy Basic Law of 1955 that builds the cornerstone for all laws and policies dealing with nuclear power in the country. In addition to the existence of a high number of other laws to form a comprehensive legal background for nuclear power, Japan is also a party to all relevant international treaties and convention on nuclear issues, while at the same time actively promoting their membership both in Asia as well as on a global stage. Sudan, on the other hand, still lacks such a comprehensive legal framework. The first law concerning the use of ionising radiation was implemented in 1971; real efforts to establish laws and policies addressing all nuclear issues have only started in the latter half of the 1990s after the implementation of the Sudan Atomic Energy Commission.

Sudan is thus still lacking a comprehensive framework and furthermore needs to become party to further international conventions dealing with nuclear power. The Nuclear Law is a big step in this direction, for now the draft is still waiting for its implementation, however (Organisation for Economic Co-operation and Development, 2011; Tarui, 2008; Eltayeb, 2013). Similar parallels can be observed in regard to the regulatory framework of both countries. Japan possesses a comprehensive apparatus of regulatory bodies to oversee its nuclear power programme. While in the past the responsibilities were divided among many different authorities, first the government reform of 1999 and subsequently the review process after the accident in Fukushima brought a streamlining of this structure. Now the Nuclear Regulation Authority is the main regulative organisation, having been set up under the Ministry of the Environment in 2012. It is charged with overseeing all important administrative tasks for the nuclear power programme, including reactor inspection. Its work is supported by several other Japanese ministries like the Ministry of Economy, Trade and Industry, which is responsible for the licensing procedures (Organisation for Economic Co-operation and Development, 2011). While the Japanese regulatory system can be seen as comprehensive and independent, especially after the rearrangements executed after 2011, the Sudanese regulatory framework is not fully developed yet. It is still lacking an autonomous regulatory body, and responsibilities have not been assigned clearly yet. However, the eventual implementation of the Nuclear Act promises to bring the much needed changes to the regulatory framework. For now the main authorities dealing with regulatory matters are the Sudan Atomic Energy Commission, the Sudanese Nuclear and Radiological Regulatory Authority, and the Ministry of Energy and Mining (Karar, 2012).

When it comes to siting, both countries follow the IAEA guidelines and standards closely. Both Japan and Sudan are faced with different challenges when it comes to site selection for a nuclear power plant. Japan, being an island nation, possesses an abundance of (sea) water needed for cooling, while suffering from high seismic activity, which calls for increased safety and security standards for its reactors. Sudan, on the other hand, is in lesser danger of experiencing a devastating earthquake; here the problem lies more with water availability as well as the accessibility of the site, seeing as its infrastructure and electricity grid are only poorly-developed at the moment. However, the Sudanese government works closely together with the IAEA and consulting agencies to find a suitable site. Thus site selection for the reactor itself cannot be seen as a problem in Sudan's case. What has been largely ignored by the government up to now, however, are sites for interim storage and final deposit of nuclear wastes, which is the only shortcoming Sudan depicts in this category (Government of Japan, 2004; Gaffar and Mukhis, 2012). When it comes to management issues, it becomes apparent that the Japanese management structure is comprehensive both for general management as well as for the nuclear cycle, which is, apart from mining and refining, fully developed in the country. Already from looking at the legislative and the regulatory framework, the detailedness of the Japanese management system can be seen. The Ministry of Economy, Trade and Industry is the main body tasked with management, ensuring that all laws and regulations are being observed. The operators of the reactors are the electrical utilities of the region the plant is located in. Japan has developed an independent nuclear cycle on both ends, only lacking mining capabilities as well as final deposit sites, the latter being developed at the moment, however. While the management structure of Japan has not been without criticism, it is nevertheless fully developed. As for Sudan, the country still needs to sort out issues concerning overlapping functions and responsibilities not yet assigned to any authority. The most important act will be the implementation of an autonomous regulatory body to oversee all activities for the introduction of the nuclear programme. Furthermore, the nuclear cycle still needs to be addressed in detail. So far the country has not developed either front end or back end capabilities, with the government for now having decided to not treat or store nuclear waste itself. As the acquisition of all services concerning the nuclear cycle are costly and also make the country dependent on outside help, the Sudanese government is advised to reassess its capabilities to do as much as possible itself (World Nuclear Association, 2014a; International Atomic Energy Agency, 2011; Gaffar and Mukhis, 2012).

The Preparedness Index is mainly based on the IAEA's Milestone Approach. When comparing the scores of the two countries, it becomes clear that these differences exist because of the times the respective country has already been working on its nuclear programme. Japan has an experience with nuclear matters going decades back to the 1960s, while Sudan has only recently concretised its interest in establishing a nuclear programme. While Sudan's progress seems to be insufficient at present, as the country closely follows the milestone approach and collaborates with the IAEA, it can be assumed that it will score higher on the Preparedness Index in the future, when more laws and policies have already been implemented.

Sustainability Index

The big ranking differences between Japan and Sudan in the Sustainability Index can be easily explained by the different stages of development the countries are in. While Japan experienced an unprecedented economic boom in the decades after World War 2 and is now one of the richest and most developed countries in the world, Sudan has been afflicted by prolonged internal conflict, which hindered progress and development.

Table 4 Development of GNI per capita between 1980 and 2013 in USD[8]

Development of GNI per capita between 1980 and 2013 in USD					
	1980	1990	2000	2010	2013
Japan	10670	27560	34970	42190	46140
Sudan	480	530	330	1190	1130

The table above shows the development of Japan's and Sudan's GNI per capita in selected years between 1980 and 2013. While the Japanese GNI has been growing steadily since after World War II, Sudan's development is uneven and slow, highlighting the detrimental role conflicts and internal strife played for the countries development. Japan had a GDP per capita of USD 36,750 in 2012, Sudan in contrast one of approximately USD 3,300 in the same year (CIA World Factbook, 2014a;b). These circumstances have profound effects on the country's capabilities of sustaining a national nuclear power programme. The Japanese economy and industry are both highly developed and continuously provide the Japanese public with employment and high living standards, despite economic troubles since the early 1990s. The economic sectioning is representative for highly developed nations, where the lion's share of the population works in the service sector and only a small fraction in agriculture. In Sudan, however, it is still the other way around. Decades of internal strife

[8] Source of the data: The World Bank (2014d): GNI per capita, Atlas method (current US$). The World Bank. [Online] http://data.worldbank.org/indicator/NY.GNP.PCAP.CD/countries/JP?page=4&display=default - accessed: July 17, 2014.

constrained economic development, for which reason eighty percent of the population still work in agriculture, mostly in subsistence farming. The difference is highlighted in the figure below.

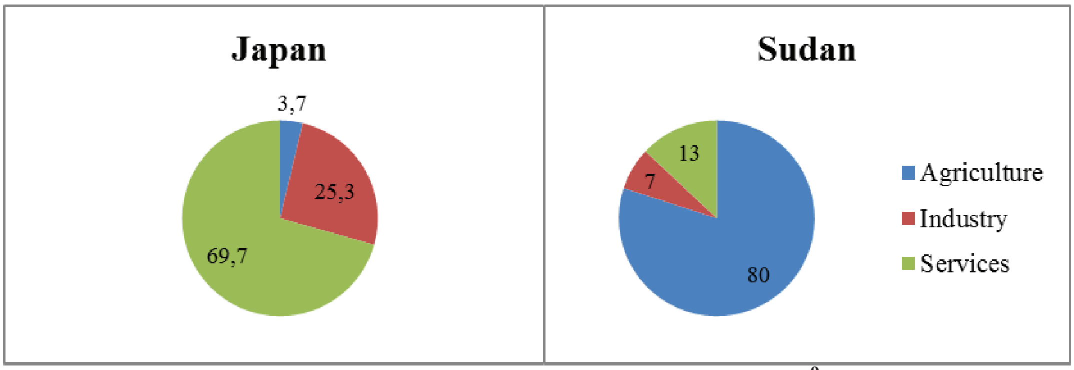

Figure 1: Share of the workforce in economic sectors (in percent)[9]

While oil revenues brought a boost to the Sudanese economy by the end of the 1990s, the secession of South Sudan slowed this development down together with high levels of inflation. Sudan has the advantage that it is largely independent from energy imports, trying to strengthen this position by building nuclear power plants. In contrast, Japan needs to import its whole fossil fuel demand, which exasperated the situation after the Fukushima accident when all remaining nuclear reactors were shut down and fuel import costs skyrocketed. Nevertheless, the Japanese infrastructure can be seen as highly developed and functional in all sectors (despite the danger of transportation infrastructure ageing, which is now being tackled by the government), which positively reflects its capabilities to sustain its nuclear power programme. For Sudan the opposite is the case. Transportation infrastructure is very poorly developed, as is infrastructure for water supply and sanitation, which is both a cause for the low living standard of the population even in cities, as well as an indicator that sustaining its nuclear power programme will be difficult for the Sudanese authorities (Ranganathan and Briceño-Garmendia, 2011; World Economic Forum, 2013).

Similar discrepancies between the countries can be found when looking at their industrial capacities. As the first country in East Asia to industrialise, the Japanese industry is highly developed and specialised. The advanced stage of the industry makes it possible for Japan to supply its nuclear power programme with domestically manu-

[9] Source of the data: Statista, 2014c; Advameg, Inc, 2014

factured parts and component, highlighting the efforts the authorities implemented to build an independent nuclear industry ever since the commissioning of the first reactor in the 1960s. Japanese expertise is that advanced and renowned that the domestic nuclear companies are now one of the few main providers of nuclear services on the international stage. Nowadays, the industry's focus lies on the development of newer, safer reactor types, the research being conducted in co-operation with facilities like the Tokyo Institute of Technology (International Atomic Energy Agency, 2011). Compared to Japan's industrial capacities Sudan's are relatively low. Next to oil drilling and refining the country's industry is concentrated in fields like textiles and cotton ginning, while, despites its abundance in mineral resources, the mining industry is only being developed slowly at present. For providing spare parts and components the Sudanese industrial capacities are not sufficiently-developed, however. For the introduction of the nuclear power programme this means that most construction and maintenance services will have to be purchased from abroad, whereas the domestic industry will only play a supporting role, providing, for example, cement if international quality standards can be met (Economy Watch, 2010).

The general development stage as well as its economic and industrial prowess influence how easily a domestic nuclear power programme can be funded and financed. While Japan can sustain its reactors with relative ease despite ongoing economic instability, the Sudanese government will be dependent on financing the better part of its nuclear programme with help from international agencies. Japan spends a yearly amount of approximately ¥ 470 billion on its nuclear programme. This sum includes all nuclear-related activities, starting with research, over disaster prevention to financing a decommissioning fund. Furthermore, the Japanese authorities demand a comprehensive funding and financing scheme from the owner of a reactor before the license is being granted. The Fukushima accident put a heavy strain on the Japanese nuclear budget, with expectations of the clean-up costs being as high as ¥ 5.81 trillion. The increasing trade deficit caused by soaring fossil fuel imports exacerbates the financial problem even further. In light of this development, the financing scheme does not seem sufficient anymore, as the recent development could have far-reaching negative effects on the country's economy. Nevertheless, in comparison to the Sudanese financial capacities, the Japanese are much farther developed and would have been sufficient if not for the accident in 2011 (World Nuclear Association, 2014a). Ever since the secession of South Sudan, the country has been running a budget deficit which was caused by the loss of oil revenue. Together with its relatively low level of development and the fact that a high number of infrastructural upgrades would need to be implemented as well, the situation is not favourable for Sudan's nuclear power programme. Without considerable financial aid the Sudanese government will not be able to finance its nuclear reactors at all. While international financial aid could help the country kick-start its programme, the analysis of Japan has shown that unforeseen accidents can destroy even the most comprehensive financial schemes, causing negative repercussions for the country's whole economy. In case of an accident in Sudan, which is relying to a considerable degree on financing, such an event would not be financially manageable.

Comparing human development and the educational system of both countries, the situation is a more favourable one for Sudan, at least when it comes to the possibilities in higher education. Japan, next to being a top performer in international testing campaigns, has developed a comprehensive scheme for ensuring the necessary human resources for operating and maintaining their nuclear power programme. The main authority responsible for education is the Ministry of Education, Culture, Sports, Science and Technology, which develops the school curricula that have a strong focus on natural sciences. Japanese universities across the country offer degrees in nuclear sciences and technologies, ensuring a continuous flow of graduates for employment in the nuclear industry. In addition to these nation-wide efforts, the operators/owners are required by law to sufficiently educate and train their personnel, which is done both in governmental as well as private training facilities (Organisation for Economic Co-operation and Development, 2012; Government of Japan, 2004; Sugimoto, 2012). In Sudan, while universities do offer similar degrees in natural sciences and fields useful for maintaining a nuclear power programme, the problem lies with primary and secondary education. The literacy rate is comparatively low and only a small percentage of the Sudanese population receives secondary education. Quality of education can also be judged to be quite low as well. While the government makes efforts to provide quality higher education and is now implementing training programmes for staff and personnel for its nuclear programme, the problem lies on a much more basic level. To ensure not only that enough young Sudanese enter nuclear-related university programmes but to also stimulate the general development of the country, the Sudanese authorities will have to improve its general educational system and devise measures to increase the percentage of the population that receives more than primary education. Without such policies the country runs the risk of having to rely on foreign specialists for its nuclear power programme (United Nations Development Programme, 2012; Karar, 2012, Eltayeb, 2013).

The Sustainability Index takes a look at factors that influence a country's ability to ensure a safe and secure operation and maintenance of its nuclear power programme. Most of the issues discussed are closely related to the general development stage of the country concerned. While the IAEA recommends a country follows the Milestone Approach to successfully introduce nuclear power on its soil, the factors presented in the Sustainability Index are largely ignored, despite the fact that they strongly influence a country's national capabilities. While the analysis showed that Japan's development in all categories is favourable to its nuclear power programme, Sudan's examination highlighted severe shortcomings in the majority of fields. If the country introduces nuclear power without vastly improving its infrastructure and financial capacities (which depend largely on its economic and industrial development) a safe and secure operation of its programme will be a severe challenge for the responsible authorities. This does not even take into consideration unforeseen events and accidents, which were discussed in the third index, the Emergency Preparedness Index.

Emergency Preparedness Index

The analysis of the Emergency Preparedness Index highlighted another important difference between Japan and Sudan that has a severe impact on the capabilities of the two counties to maintain their nuclear power programmes: their political stability.

As can be seen in the table below, while Japan is not one of the top ranking stabile countries according to the Failed State Index, it is nevertheless categorised as having a good political stability. Japan experiences mounting pressure from demographic change and economic decline, yet these do not have a direct negative effect on a safe and secure operation of a nuclear power programme unless they become more pressing. For Sudan the situation is less favourable: the country scores the third rank in the Failed State Index, making it one of the least stable countries in the world. Sudan suffers from internal conflicts and a large number of displaced people and refugees. Economic troubles exacerbate these problems, causing riots which further undermine the political stability. In addition, the Sudanese government itself is being criticised in the study, highlighting internal power struggles. All these issues have negative repercussions for a nuclear power programme. Sudan is very instable and also a location for terrorist activities. There is the potential risk that religiously-motivated groups could benefit from the tenuous security environment and either compromise the nuclear power programme or steal radioactive material that could potentially be used for the construction of weapons. Looked at Sudan from this perspective, the country does not seem prepared for its own nuclear programme (Fund for Peace, 2013; Sudan Tribune, 2009).

Table 5: The Failed States Index 2013: Japan and Sudan[10]

Country	Rank	Total	Demographic Pressures	Refugees and IDPs	Group Grievance	Human Flight	Uneven Development	Poverty and Economic Decline	Legitimacy of the State	Public Services	Human Rights	Security Apparatus	Factionalized Elites	External Intervention
Sudan	**3,0**	**111,0**	8,8	10,0	10,0	8,4	8,5	7,8	9,6	8,8	9,3	9,8	10,0	10,0
Japan	**156,0**	**36,1**	5,4	3,7	3,8	2,0	1,8	3,7	2,2	2,5	3,0	1,7	2,6	3,7

Shortcomings also become apparent when looking at the other three categories. While Japan's health care system and infrastructure faces growing challenges due to the country's aging population and primary emergency response failed to adequately work in March 2011 because of a lack of emergency planning, it nevertheless well-developed and sophisticated. Not only is the Japanese health infrastructure prepared to treat all kinds of general ailments of the population, it also possesses the expertise and technologies to deal with nuclear events on any scale. Sudan, on the other hand, possesses only a rudimentarily developed health infrastructure. While government spending has risen in the last years, the health care systems still suffers severe shortcomings, especially in rural areas where treatment is hard to come by. Furthermore, the general quality of health services is relatively low, a fact that is exacerbated by a

[10] Source of data: The Fund for Peace, 2014.

brain drain of doctors to other countries. Capabilities to deal with nuclear accidents are being developed only now; however, to be able to react in a sufficient and timely manner in case of such an event, the Sudanese government will have to invest a lot of money to first strengthen and expand the basic medical infrastructure before it can develop strategies for nuclear treatment in case of an accident (Organisation for Economic Co-operation and Development, 2013; ENENews, 2012; World Health Organisation, 2009; Syeed, 2014).

Similarly, the Japanese disaster management system is well-developed while Sudan's is not. Japan, as a country prone to disaster, has developed a comprehensive framework to deal with environmental hazards and man-made accidents of any kind. It follows the recommended "prevention, response and recovery" approach and has achieved one of the highest standards for earthquake safety in the world. While the system is generally working very well, shortcomings became evident during the Fukushima accident, when it was shown that the Japanese government failed to take low-probability events into account in its emergency plans. The governance of the event was consequently also criticised, an issue which has already been addressed in the last few years (Government of Japan, 2011; The World Bank, 2012). In Sudan, the disaster management system is less well-developed. The country also routinely experiences disasters, especially in the form of droughts and flooding, yet the government continuously needs to rely on foreign help to deal with such events. While two main policies for disaster management exist, only one of them has been implemented so far, and a comprehensive framework incorporating the three issues - prevention response and recovery - still needs to be devised and put into force. The main issue at the moment is the dependence of international aid as this circumscribes Sudan's capabilities to react to a disaster (PreventionWeb, 2014; World Health Organisation, 2010).

The last category in the Emergency Preparedness Index is directly related to a country's nuclear power programme: radiation protection and management. Japan's monitoring infrastructure is well-developed, with monitoring stations being located both in the reactors themselves, their vicinity, as well as across the whole country to guarantee continuous monitoring of radiation levels. Japan has implemented international standards in its national infrastructure to ensure the safety of its population. However, while the country possesses the technical expertise to do so, the lack of transparency, which lead to data being withheld, was one issue that was criticised during the Great East Japan Earthquake. Furthermore, clearly designated radiation shelters to which the population could flee during the accident were also lacking, which meant that evacuees were brought to shelters that were not adequately equipped for events related to ionising radiation. While the construction of such shelters was enacted in 2013, they were missing in 2011 (Organisation for Economic Co-operation and Development, 2010; Government of Japan, 2004; KYODO, 2012b, Bird, 2012). Sudan's radiation management has mostly focussed on regulatory concerns up to now, especially the designation of the responsible authorities like the Sudan Atomic Energy Commission and the Sudanese Nuclear and Radiological Regulatory Authority. Legislation and policies dealing with general radiation issues have been implemented too, the issue now lies with providing the necessary infrastructure for radiation protection and management. Here again, financial constraints cause problems, which will need to be addressed before the first reactor starts operating. Nevertheless, when it comes to regulatory considerations, the Sudanese government has implemented important measures for radiation protection; now they only need the support of a functioning safety and monitoring infrastructure (Elamin, 2001; Osman et al., 2009).

Analysis the two countries using the Emergency Preparedness Index highlighted the difficulties governments are faced with to ensure safety for its population and the general environment even in case of emergency. Not only policies and measures concerning protection in case of nuclear accidents need to be in place, a functioning health infrastructure, as well as a comprehensive disaster management system are prerequisites for being able to react in a sufficient and timely manner in such an event. Political stability is a basic consideration in this index, as it is both necessary to allow the governance in case of emergency and to ensure that the nuclear power programme is not likely to be compromised by hostile groups or terrorist actors.

Results of the evaluation

This chapter showed that there are hardly any similarities between the Japan and Sudan when it comes to their capabilities of implementing and sustaining a nuclear power programme. Most of the differences are caused by two factors: the first one is their stage of development. The higher developed a country, the easier it is to finance such an endeavour. As being well-developed also means that a comprehensive infrastructure is already in place, only small adaptions to accommodate a nuclear programme will have to be made. The second factor is the time that the countries have already been dealing with nuclear power. The longer a country has already been working on or with a nuclear power programme, the more likely it is that their laws, regulations, and policies are sufficiently developed. This is also the case for its economy, infrastructure, and education. If a country, as is the case with Japan, has been utilising nuclear power for decades already, it can be expected that national capabilities to maintain its nuclear programme have been sufficiently developed.

Sudan is in both regards completely different from Japan. It is a fairly poorly-developed country lacking the financial means and infrastructural preconditions to implement a nuclear programme without difficulties. Furthermore, it only recently decided on introducing nuclear power on its soil, which means that it has neither the capabilities nor experience to implement and maintain its nuclear programme without outside help yet. As the analysis and subsequent evaluation showed, Sudan reached the best results in the Preparedness Index, as legislative and regulatory changes are comparatively easy to implement. The main issues for countries planning to introduce nuclear reactors have been addressed in the Sustainability Index and the Emergency Preparedness Index, which is also where the main challenges for Sudan lie at the moment.

4.2 Recommendations for the IAEA Milestone Approach

The purpose of this study was to assess the general preparedness of countries for introducing a national nuclear power programme. For this purpose the Critical Powers Index was developed in Chapter 2, which, in its first sub index, draws on the IAEA's Milestone Approach to analyse a country's preparedness in terms of laws, regulatory authorities and management issues, including siting. As the assessment of Sudan has shown, otherwise less capable countries can achieve comparatively high scores in the Preparedness Index, if they follow the guidelines the IAEA has published for the introduction of a nuclear power programme. However, in course of the analysis it became also apparent that a high score in that first index does not adequately represent a country's general preparedness. Indeed, just from looking at Sudan's score it received in the Preparedness Index, its capabilities to introduce and handle nuclear power might even be overestimated. While a comprehensive legislative and regulatory framework addressing all issues regarding a nuclear power programme is without a doubt important, a country's real capabilities depend more on the factors presented in the Sustainability and Emergency Preparedness Index.

The International Atomic Energy Agency is, as was already explained in the beginning of the study, tasked with the promotion of nuclear techniques and power for peaceful processes. From that standpoint it is understandable that it will not restrain interested countries more than is absolutely necessary, nor does it possess the power to interfere in the internal affairs of sovereign states on issues that do not first and foremost concern nuclear power. Nevertheless, as the analysis has shown, the Milestone Approach would need to be revised to such an extent as to also include considerations about the general development of a country, seeing as it factors strongly into the financial and technical capabilities to sustain a nuclear programme once it has been implemented. Especially the industrial and economic development need to be taken into consideration as these two factors strongly influence other issues like financial capabilities and the population's education as well. Furthermore, while the Milestone Approach addresses radiation protection and management, the preparedness for nuclear events also depends on infrastructural issues concerning the health infrastructure, as well as plans for general disaster management. If a country fulfils neither of the two issues, its radiation protection framework will not be sufficient, as a functioning health infrastructure and emergency plans are absolutely necessary to protect the population in case of nuclear emergency.

Because of the reasons already outlined above, it will not be easy for the IAEA's policy makers to incorporate the factors concerned into the Milestone Approach, as they go far above the goal of the document to reach a minimum preparedness for introducing nuclear power in a country. As a country's progressive development can be considered a cornerstone even more important than a functioning legislative and regulatory framework, the IAEA would be advised to include other international organisations or advisory teams to also work together with the country interested in a nuclear programme to implement measures to develop a sufficient infrastructure and conditions favourably to the maintenance of the programme. This also includes the issues presented in the Emergency Preparedness Index like the health infrastructure and the capabilities to handle disasters of any kind. Only if, with the help of international actors like the IAEA, a country addresses all these issues, it can be judged as prepared for a nuclear power programme.

The inclusion of the factors presented above will prolong the introduction of nuclear power in a country substantially. Nevertheless, it is important that all these issues are addressed, as no matter how well prepared, unforeseen events can have far-reaching effects on a country, as was seen in the case of Japan. Nuclear accidents will always prove a challenge to the affected country, which makes it even more important that a nuclear candidate is prepared to its fullest potential to minimise negative effects on its environment and people as well as its economy. A revision of the Milestone Approach to include the issues discussed will prolong the introduction of nuclear power in a country, which had been designed to be around 15 years. It will also make the assessment process more complex and thus also more costly for the country that goes through that process. However, for the safety of the future programme it can be seen as an important step, which could also improve the opinion of the general public about nuclear power in general.

5. Conclusion

The purpose of this study was to develop an overarching index to assess whether a country is capable of introducing and sustaining a domestic nuclear power programme. To measure national capabilities as well as strengths and weaknesses, the Critical Points Index has been developed in chapter 2 of this study. The Critical Points Index is composed of three separate indices which address specific issues concerning the introduction and maintenance of a nuclear power programme. The first index is called the Preparedness Index and incorporates the factors the International Atomic Energy Agency highlights in its Milestone Approach for countries trying to embark on a nuclear programme. It addresses legal and regulatory issues, including questions concerning site selection and general management that needed to be administered to get the support of the IAEA and the international community for this endeavour. Compared to the other two indices, the problems highlighted in this first index were less important than those of the other two, as was reflected in the weighting factor of 1 applied to this sub-index. The second index, the Sustainability Index, deals with general developmental issues. The successful introduction of a nuclear power programme is largely dependent on the general capabilities of the country concerned. As became apparent in the Sustainability Index, infrastructure and economic development significantly impact national competences, so do financial means and the educational level of the country's population. As the subsequent analysis showed, it is especially the factors discussed in this index that influence how independent the country concerned will be in both constructing and sustaining its reactor(s). Especially the latter is of central importance, as it is this, up to forty year long, stage of the nuclear programme that the country will need to operate mostly without outside help. For this reason, the Sustainability Index was given a weighting factor two, showing its unrivalled importance. The third index, the Emergency Preparedness Index, was given a weighting factor of 1.5, as the preparedness to deal with both minor and major (nuclear) accidents is essential for a safe and secure maintenance of a country's nuclear power programme. Not only issues directly related to radiation protection and monitoring were taken into account in this index, the political stability of the country concerned as well as its health infrastructure and general disaster preparedness were analysed too. In total, the Critical Powers Index was given 450, of which at least sixty percent should be achieved to be able to introduce and maintain a domestic nuclear power programme without relying too much on help of the international community.

The Critical Powers Index was subsequently, in chapter 3 of this study, used to analyse two countries. The first, Japan, is a country with a long history with nuclear energy and thus was awarded with 402.5 points at the end of the analysis. It has been shown that Japan's long experience with its nuclear programme that goes back to the 1960s resulted in its high expertise. The country was awarded 95 (out of 100) and 180 (out of 200) points for the first two indices, highlighting the sophistication of Japan's nuclear power programme as well as the fact that Japan is one of the richest and most developed countries in the world with an infrastructure developed to such an extent as to be able to sustain its nuclear programme without any difficulties. The only deficits the country depicted could be seen in the Emergency Preparedness Index, where Japan was only awarded with 127.5 (out of 150) points. Japan's problems in dealing with the Fukushima accident in March 2011, that was the result of a double disaster, highlighted the fact that no matter how advanced a country and its technology, preparedness for nuclear events has to be given special attention.

The second country that was analysed in this study and which stands representative for all developing countries that plan to embark on a nuclear programme in the foreseeable future is Sudan. Sudan plans to introduce nuclear energy until 2019 with the help of the IAEA and foreign contractors, yet the analysis using the Critical Powers Index showed that it will be faced with severe challenges. Sudan is considerably less developed than Japan, which causes severe difficulties as became apparent when looking at the Sustainability Index and the Emergency Preparedness Index, for which the country was awarded 65 (out of 200) and 40 (out of 150) points respectively. The comparatively high score Sudan reached in the Preparedness Index (50 out of 100) furthermore showed that this index is comparatively less important for accessing a country's capabilities. Because of its severe shortcomings in its economic and infrastructural development as well as the issues concerning medical care and disaster management, Sudan cannot be judged to be adequately prepared for introducing nuclear power without relying too much on international support. The country's overall score was only 155 and thus still far from the 270 that the author of this study recommended as a minimum for introducing a nuclear power programme.

The analysis of Japan and Sudan can be seen as representative for all the other, mostly developing, countries that are interested in introducing nuclear power in the near future. Sudan, as one of the least developed and least stable countries, thus highlights all the difficulties those countries will be faced with. As became apparent in the course of the analysis, legal and regulatory frameworks are comparatively easy to implement, even for countries with an otherwise low level of development. The real challenges lie with much more "basic" issues like the development of the economy and infrastructure, or even the educational level of the population. It is because of this reason that the IAEA Milestone Approach can be seen as not comprehensive enough. It only deals with issues directly related to a nuclear power programme, while the factors discussed in the other two indices of the Critical Powers Index are largely ignored or seen as prerequisites. However, an insufficiently developed infrastructure and an only rudimentarily developed industry make the introduction and especially the maintenance of a nuclear power programme much more difficult. Similarly, an adequate preparedness for nuclear events requires a basic development of a medical infrastructure as well as an existing disaster management framework, which is also not given due attention in the Milestone Approach.

In light of the results of this study, it is recommended that the IAEA Milestone Approach be reviewed and amended to include considerations about the general level of development of the country concerned. This will result in a much more complicated assessment process, for which reason it is also recommended to extent the introductory period of 15 years to such an extent that improvements to infrastructure, the educational system as well as general disaster management can be conducted. While this will lead to a longer and more costly introductory process, it will nevertheless ensure a safe nuclear power programme that is less prone to errors and accidents.

The question of this study was whether, according to the Critical Powers Index developed for this purpose, Japan and Sudan are prepared for introducing and sustaining a nuclear power programme. In light of their scores reached in chapter 3, the answer is yes for Japan, whereas Sudan is advised to postpone the construction of its first reactor until its general level of development has increased substantially.

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