

## 6 REGULATORY ASPECTS

### 6.1 INTRODUCTION

Appropriate regulations and efficient regulatory bodies are of utmost importance in any technology, but even more so in the nuclear industry considering public acceptance and the potential occurrence of a catastrophic hazard such as Chernobyl (even though it is extremely unlikely that a similar event could occur). Moreover, the importance of these aspects may become even more pronounced in the proposed nuclear-assisted production of hydrogen technology where two critical facilities are combined and often co-located (thermochemical cycles). While safety (discussed in Chapters 4 and 5) is universal, regulatory aspects are local and establishing efficient regulatory bodies will be the responsibility of the local government. However, determining and/or attaining appropriate regulations will be considerably more complex.

Since the purpose of this chapter is not to address all regulations involved with a nuclear or chemical facility, but rather to address the regulations that may come into play when the two facilities are combined and co-located, consider the co-location of regulatory-approved, stand-alone nuclear and chemical facilities of general design. In this regard, it is assumed that without connection the nuclear and chemical facilities are constructed and operated according to the applicable safety standards and regulations imposed by their governing regulatory bodies. In this manner, only the regulatory issues that arise due to co-location and connection of the two facilities are investigated. While the purpose of Chapter 5 was to identify and investigate the technological and safety aspects of a combined nuclear/chemical complex, if it is assumed that the technology involved with connecting the facilities are available and approved, only the safety aspects require investigation with regard to possible regulatory issues. Therefore, the regulatory aspects related to the HTGR plant reduces to co-location with a chemical production facility, the resultant nearness of hazardous chemical inventories, thermal and pressure turbulences in the primary circuit and the ingress of foreign media into the nuclear reactor. Similarly, the regulatory aspects related to the chemical plant reduces to co-location with a HTGR, thermal and pressure transients in the process section and intrusion of radioactive and other foreign media (intermediate coolant such as helium) into the chemical process and ultimately the hydrogen and/or other products (synthesis gas, oxygen). Regarding the chemical facility, co-location with a HTGR and thermal and pressure

transients are unlikely to affect regulations such that it may impede implementation of the technology. However, the transport of radioactive material into the process circuit and the resultant product is of some concern, probably more a political issue than a safety issue as stated in Forsberg *et al.* (2007). Regardless, it will play a role in the ultimate success and widespread implementation of the technology. To this extent, under normal operating conditions, tritium is the only fission product that is able to permeate through the IHX in significant quantities to warrant investigation (Forsberg *et al.*, 2007). The consequence of tritium permeation is radioactive contamination of the process circuit and hydrogen product, which pose a health risk to the operating personnel and the consumers respectively. Although the attendant risk is relatively minor compared to core damage and release of radioactive materials from the nuclear containment, it will be an issue regulated by the governing authorities.

In contrast to the chemical plant issues, the location of a chemical facility in close proximity to a HTGR will be a major issue for nuclear regulators and may even be the decisive factor regarding the feasibility of the thermochemical technologies. Several issues arise when the production facility is near to the HTGR, including peak pressures and heat radiation from combustions originating at the chemical complex, as well as the transport of corrosive, toxic, asphyxiate and/or flammable gases (especially oxygen) to the nuclear plant and nuclear plant control room. Thermal and pressure transients in the primary system of the nuclear plant will probably be anticipated events and will therefore not pose significant deterrents during development and implementation of the technology. However, the authorities will regulate these aspects as well as the ingress of foreign material into the primary circuit of the nuclear plant, which will necessitate defence-in-depth strategies and single-failure criteria (a system must be capable of performing its task in the presence of any *singe failure*; IAEA, 2007). Therefore, the main regulatory issue regarding the nuclear/chemical complex is that of the hazardous chemical inventory situated close to the HTGR. As discussed in the previous two chapters, the consequences of the hazards associated with the hazardous chemical inventories decrease as the separation distance between the facilities increases.

Since nuclear regulations are significantly stricter than that of chemical facilities, one of the most important aspects to consider is where the interface between the nuclear and chemical facilities is judged to be, especially considering directly coupled plants. However, most nuclear-hydrogen production technologies utilize an intermediate heat exchanging circuit such that the hydrogen production facility may operate

according to chemical facility standards and the HTGR and IHX according to nuclear standards.

Since most of the information in this chapter regards legal requirements and regulations, much of it is quoted from the applicable sources in order to reduce the possibility of misinterpreting the regulations or requirements. As an added preventative measure with regards to misinterpretation of the Acts, the definitions as they are applicable to the Act are given before each Act is discussed. Some terms differ in meaning or extent from one Act to another and are correspondingly defined in the definitions pertaining to that Act. Although it is customary to situate definitions of terms in an Appendix, practicality and ease of reading was considered more important and resulted in the definitions being explained within the main report.

Lastly, since the US regulations that may play a role during licensing of the combined complex were examined in the previous chapter (Chapter 5), the first aspect to consider in this chapter is that of national (South African) regulatory aspects.

## **6.2 NATIONAL REGULATIONS**

The governing of nuclear energy and nuclear installations in South Africa is achieved by the Nuclear Energy Act (Act No. 46 of 1999) and the National Nuclear Regulator Act (Act No. 47 of 1999) respectively. However, since the combined complex includes a chemical production facility, several other acts may need to be incorporated to effectively govern nuclear assisted hydrogen production facilities. One of these acts will be the Hazardous Substances Act (Act No. 15 of 1973), and since this Act is referenced in both of the nuclear related acts, it is discussed first.

### **6.2.1 HAZARDOUS SUBSTANCES ACT**

The purposes of the Hazardous Substances Act (Act No. 15 of 1973) are:

- *“to provide for the control of substances which may cause injury or ill health to or death of human beings by reason of their toxic, corrosive, irritant, strongly sensitizing or flammable nature or the generation of pressure thereby in certain circumstances, and for the control of certain electronic products;*

- *to provide for the division of such substances or products into groups in relation to the degree of danger;*
- *to provide for the prohibition and control of the importation, manufacture, sale, use, operation, application, modification, disposal or dumping of such substances and products; and*
- *to provide for matters connected therewith"*

In order to describe this Act, the following table (Table 6-1) is a summary of the pertinent terms and their explanations as they are applicable to the Act (quoted from section 1 of this Act).

**Table 6-1: Definitions pertaining to the Hazardous Substances Act (Act no. 15 of 1973)**

Term	Explanation
dump	in relation to a grouped hazardous substance, means deposit, discharge, spill, release or cause or permit to be deposited, discharged, spilled or released (whether or not the substance in question is enclosed in a container), in such a place, under such circumstances or for such a period that the person depositing, discharging, piling, or releasing or causing or permitting it to be deposited, discharged, spilled, or released, may reasonably be assumed to have abandoned it; and "dumping" has a corresponding meaning
electronic product	(a) any manufactured product which, when in operation, contains or acts as part of an electronic circuit; and
	(i) emits (or in the absence of effective shielding or other controls would emit) electronic product radiation; or
	(ii) or would, as a result of the failure or breakdown of any built-in safety measure or shielding, pose an electrical, mechanical, chemical, biological, ergonomic or other hazard, or cause excessive temperature, excessive pressure or ignition of flammable material, which may cause injury, ill health or death to human beings
	(b) any manufactured article which is intended for use as a component, part or accessory of a product described in paragraph (a) and which, when in operation
electronic product radiation	(i) emits (or in the absence of effective shielding or other controls would emit) such radiation; or
	(ii) would, as a result of the failure or breakdown of any built-in safety measures or shielding, pose an electrical, mechanical, chemical, biological, ergonomic or other hazard, or cause excessive temperature, excessive pressure or ignition of flammable material, which may cause injury, ill-health or death to human beings
grouped	(a) any ionizing or non-ionizing electro-magnetic or particulate radiation; or
	(b) any sonic, infrasonic or ultrasonic wave which is emitted from an electronic product as the result of the operation of an electric circuit in such product
grouped	any Group IV hazardous substance and any substance, mixture of

hazardous substance	substances, product or material declared in terms of section 2 (1) ( <i>Group I, II or III</i> ) to be a hazardous substance of any kind
Group I and II Hazardous Substance	any substance or mixture of substances which, in the course of customary or reasonable handling or use, including ingestion, might, by reason of its toxic, corrosive, irritant, strongly sensitizing or flammable nature or because it generates pressure through decomposition, heat or other means, cause injury, ill health or death to human beings
Group III Hazardous Substance	any electronic product
Group IV Hazardous Substance	fabricated radio-isotopes contemplated in the definition of "radioactive material" in section 1 of the Nuclear Energy Act (Act No. 46 of 1999), which are outside a nuclear installation as defined in the said Act and
	(a) have an activity concentration of more than 100 Becquerel per gram; or
	(b) have an activity concentration of 100 Becquerel or less per gram and which the Minister has by notice in the Gazette declared to be a Group IV hazardous substance
	and which are used or intended to be used for medical, scientific, agricultural, commercial or industrial purposes

According to section 2 of the Act, the Minister of Health may declare any product, substance or composition of substances to be a Group I, II, III or IV hazardous substance in accordance with the applicable definition stated in the table above. Moreover, section 29 allows the Minister of Health to make regulations regarding every act concerning hazardous substances.

Section 3 of the Act determines the conditions regarding the "*Sale of Group I and Group III (hazardous substances) and letting, use, operation, application and installation of Group III, hazardous substances*". To this extent, no person may:

- (a) *"sell any Group I hazardous substance -*
  - a. *unless he is the holder of a license issued to him in terms of section 4 (a); and*
  - b. *otherwise than subject to the conditions prescribed or determined by the Director-General;*
- (b) *sell, let, use, operate or apply any Group III hazardous substance unless a license under section 4 (b) is in force in respect thereof, and otherwise than subject to the conditions prescribed or determined by the Director-General;*
- (c) *install or keep installed any Group III hazardous substance on any premises unless a license under section 4 (c) is in force in respect of such premises, and otherwise than subject to the conditions prescribed or determined by the Director-General."*

Section 4 of the Act is concerned with the "*Production, acquisition, disposal, and importation and exportation, of Group IV hazardous substances*" such that:

- (1) "*Subject to the provisions of this section, no person shall produce or otherwise acquire, or dispose of, or import into the Republic or export from there, or be in possession of, or use, or convey or cause to be conveyed, any Group IV hazardous substance, except in terms of a written authority under subsection (2) and in accordance with-*
  - (a) *the prescribed conditions; and*
  - (b) *such further conditions (if any) as the Director-General may in each case determine.*
- (2) *The Director-General may on application by any person in the prescribed manner and on payment of the prescribed fee, and on such conditions as he may in each case determine, in writing authorize the performance of any of or all the activities mentioned in subsection (1) in respect of any Group IV hazardous substance."*

While in subsection 5:

- "The Minister may from time to time by notice in the Gazette-*
- (a) *determine that any provision of subsection (1) shall not apply in respect of any Group IV hazardous substance mentioned in the notice; or*
  - (b) *exempt any person or category of persons from any provision of subsection (1),*
- and may in like manner at any time amend or withdraw such notice."*

In the Government Gazette of 23 February 1993, R. 247 concerns the Regulations Relating to Group IV Hazardous Substances, with the dose limits as specified in Annexure 2 of the regulation given in the following table (GG, 1993; Table 6-2).

**Table 6-2: Dose Limits (GG, 1993)**

Application	Occupational Dose Limit	Public Dose Limit
Effective Dose	20 mSv per annum averaged over 5 years and not more than 50 mSv in any 1 year	1 mSv per annum
Annual equivalent dose to the-		
Eye(s)	150 mSv	15 mSv
skin	500 mSv	50 mSv
hands and feet	500 mSv	(not given)
abdomen of pregnant woman	2 mSv	(not given)

It is important to note that Group IV hazardous substances are radioactive material outside a nuclear installation and has a radioactivity of more than 100 Bq/g or was determined by the Minister of Health to be a Group IV hazardous substance. Considering the nuclear/chemical complex and assuming that the production facility will be part of the nuclear installation, the hydrogen product containing a small amount of tritium could be classified as a Group IV hazardous substance. However, it is inconceivable that the tritium content in hydrogen would be such that the product will have an activity in excess of 100 Bq/g (Japanese designers propose less than 12 Bq/g; Forsberg *et al.*, 2007). Therefore, the hydrogen product could only be classified as a Group IV hazardous substance if the Minister determines it as such, which is extremely unlikely to occur. However, the chemical production facility has a significant inventory of (other) hazardous substances that could be classified as Group I or II hazardous substances due to their flammable, corrosive, toxic or asphyxiate characteristics.

### 6.2.2 NUCLEAR ENERGY ACT

The Nuclear Energy Act (Act No. 46 of 1999) has the following objectives that serve as foundation of the act:

- *“to provide for the establishment of the South African Nuclear Energy Corporation Limited, a public company wholly owned by the State, to define the Corporation’s functions and powers and its financial and operational accountability, and provide for its governance and management by a board of directors and a chief executive officer;*
- *to provide for responsibilities for the implementation and application of the Safeguards Agreement and any additional protocols entered into by the*

*Republic and the International Atomic Energy Agency in support of the Nuclear Non-Proliferation Treaty acceded to by the Republic;*

- *to regulate the acquisition and possession of nuclear fuel, certain nuclear and related material and certain related equipment, as well as the importation and exportation of, and certain other acts and activities relating to, that fuel, material and equipment in order to comply with the international obligations of the Republic;*
- *to prescribe measures regarding the discarding of radioactive waste and the storage of irradiated nuclear fuel; and*
- *to provide for incidental matters”*

In order to describe this Act, the following table (Table 6-3) is a summary of the pertinent terms and their explanations as they are applicable to the Act (quoted from section 1 of the Act).

**Table 6-3: Definitions pertaining to the Nuclear Energy Act (Act no. 46 of 1999)**

Term	Explanation
disposed of	used in the context of safeguards means sell, exchange, donate, distribute, lend or in any other manner transfer and “disposal of” has a corresponding meaning
enrich	increase the ratio of an isotopic constituent of an element to the remaining isotopic constituents of that element relative to the naturally occurring ratio, and “enrichment” has a corresponding meaning
ionizing radiation	electromagnetic or corpuscular emission emitted from radioactive material and capable of producing ions, directly or indirectly, while passing through matter
nuclear fuel	any material capable of undergoing a nuclear fission or nuclear fusion process on its own or in combination with some other material and which is produced in a nuclear fuel assembly or other configuration
nuclear material	source material and special nuclear material
Nuclear Non-Proliferation Treaty	the Treaty on the Non-Proliferation of Nuclear Weapons acceded to by the Republic on 10 July 1991
process	when used as a verb in relation to source material, special nuclear material and restricted material, means to extract or recover such a material or to concentrate, refine or convert it in any manner without enriching it, and “processing” has a corresponding meaning
radioactive material	any substance consisting of, or containing, any radioactive nuclide, whether natural or artificial
radioactive nuclide	an unstable atomic nucleus which decays spontaneously with the accompanying emission of ionizing radiation
radioactive waste	any radioactive material destined to be disposed of as waste material
reprocess	to extract or separate, from source material or special nuclear material



	that has been subjected to radiation, the constituents that have undergone transmutations as a result of the radiation, or the constituents that have not undergone those transmutations and are re-usable
Safeguards Agreement	the comprehensive safeguards agreement entered into on 16 September 1991 between the Republic and the International Atomic Energy Agency with regard to the application of safeguards for the purposes of the Nuclear Non-Proliferation Treaty pursuant to the Republic's accession to that Treaty on 10 July 1991
storage facility	a facility for the acceptance, handling and treatment of irradiated fuel and the storage thereof
waste disposal facility	a facility for the acceptance, handling, storage and treatment of radioactive waste and irradiated fuel and the disposal of radioactive waste

With respect to the operation of nuclear installations, the Nuclear Energy Act has no relevance. However, during research and development of the combined complex it will be fundamental, especially considering the main functions of the South African Nuclear Energy Corporation Limited (Necsa), which according to section 13 of the Act are:

- (a) *"to undertake and promote research and development in the field of nuclear energy and radiation sciences and technology and, subject to the Safeguards Agreement, to make these generally available;*
- (b) *to process source material, special nuclear material and restricted material and to reprocess and enrich source material and nuclear material; and*
- (c) *to co-operate with any person or institution in matters falling within these functions subject to the approval of the Minister"*

Moreover, the Act regulates the acquisition and possession of certain nuclear related material and equipment. As published in the Government Gazette of 13 June 2008, in terms of section 2(a), (b), (c) and (f) of the Nuclear Energy Act, the Minister of Minerals and Energy declares the following substances, materials and equipment as restricted material, source material, special nuclear material, and nuclear related equipment and material (GG, 2008):

1. *"Restricted material:*

a. *Beryllium*

- i. *Metal and alloys containing more than 50 wt.% beryllium*
- ii. *Compounds containing beryllium*
- iii. *Manufacturing of (i) or (ii), except for*

1. *Metal windows for X-ray machines*
      2. *Electronic component parts or electronic circuits*
      - iv. *Waste and scrap containing beryllium as defined in (i) or (ii)*
    - b. *Hafnium*
      - i. *Metal, alloys or compounds containing more than 60 wt.% hafnium*
      - ii. *Manufacturing of (i)*
    - c. *Zirconium*
      - i. *Metal and alloys containing more than 50 wt. % zirconium*
      - ii. *Compounds in which the ration of hafnium content to zirconium content is less than 1 part to 500 parts by mass*
      - iii. *Manufacturing of (i) or (ii), except for*
        1. *Zirconium foil with thickness less than 0.10 mm*
      - iv. *Waste and scrap containing zirconium as defined in (i) or (ii)*
2. *Source material:*
  - a. *Uranium, expressed as a conversion to  $U_3O_8$  above*
    - i. *0.05 wt. % of the substance*
    - ii. *A mass of 3 kg*
  - b. *Thorium, expressed as a conversion to  $ThO_2$  above*
    - i. *0.05 wt. % of the substance*
    - ii. *A mass of 3 kg*
  - c. *Uranium, depleted in the isotope 235*
    - i. *A mass above 3 kg*
3. *Special nuclear material:*
  - a. *Plutonium-239*
  - b. *Uranium-233*
  - c. *Uranium enriched in its uranium-235 isotope*
  - d. *Trans-uranium elements*
  - e. *Compounds, substance or substances containing more than 0.5 g of substances (b), (c) and (d), regardless of the concentration thereof.*
4. *Nuclear related material:*
  - a. *Deuterium and heavy water*

- i. Deuterium, heavy water (deuterium oxide) and any other deuterium compound in which the ratio of deuterium to hydrogen atoms exceeds 1:5000 for use in a nuclear reactor*
  - b. Nuclear grade graphite*
    - i. Graphite having a purity level better than 5 ppm boron equivalent and with a density greater than 1.5 g/cm<sup>3</sup>.*
- 5. Nuclear related equipment:*
  - a. Reactors and equipment there for*
  - b. Plants for the reprocessing of irradiated fuel elements and equipment*
  - c. Plants for the fabrication of fuel elements*
  - d. Plants for the separation of isotopes of uranium and equipment, other than analytical instruments, especially designed or prepared there for*
  - e. Plants for the production of heavy water, deuterium and deuterium compounds and equipment especially designed and prepared there for*
  - f. Plants for the conversion of uranium and plutonium for use in the fabrication of fuel elements and the separation of uranium isotopes and equipment especially designed or prepared there for"*

Furthermore, in terms of section 2(e) and (g) of the Nuclear Energy Act, the Minister of Minerals and Energy may respectively:

- *"Exempt any radioactive material from the provisions of this Act" and*
- *"Determine the levels of specific activity and total activity of radioactive material below which the provisions of this Act do not apply"*

Chapter III of the Nuclear Energy Act (sections 33 to 43) is concerned with Nuclear Non-Proliferation relating to the Safeguard Agreement, the Nuclear Non-Proliferation Treaty, any additional protocols regarding non-proliferation and the Non-Proliferation of Weapons of Mass Destruction Act (Act No. 87 of 1993). Nuclear non-proliferation allows for the use of nuclear energy for peaceful purposes while deterring its use for non-peaceful purposes. Article IV of the Nuclear Non-Proliferation Treaty substantiates the peaceful use of nuclear energy such that:

- *“Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and inconformity with Articles I and II of this Treaty.*
- *All the Parties to the Treaty undertake to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy.*
- *Parties to the Treaty in a position to do so shall also co-operate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of non-nuclear-weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world.”*

While section 44 of the Nuclear Energy Act (1999) allows for the acquisition of source material and restricted material by the State, sections 45 and 46 regard the management and discarding of radioactive waste and storage of irradiated nuclear fuel. However, these sections are not applicable to Group IV hazardous substances, exempted radioactive material or radioactive material with activity levels below those specified in section 2(g). Therefore, this Chapter of the Act (Chapter IV) has no relevance to the chemical production facility or the hydrogen product, but the nuclear waste generated at the nuclear plant will have to adhere to the provisions of this Act regarding radioactive waste management and storage of irradiated nuclear fuel. In 2005, the DME established a radioactive waste management policy and strategy for the Republic of South Africa, which include the international policy principles of the IAEA as well as additional national policy principles (DME, 2005d). The classification of radioactive waste and the possible waste management options associated with each level are given in Appendix B.

### 6.2.3 NATIONAL NUCLEAR REGULATOR ACT

The National Nuclear Regulator Act (Act no. 47 of 1999) has the following objectives:

- *“to provide for the establishment of a National Nuclear Regulator in order to regulate nuclear activities, for its objects and functions, for the manner in which it is to be managed and for its staff matters”*
- *“to provide for safety standards and regulatory practices for protection of persons, property and the environment against nuclear damage”*
- *“to provide for matters connected therewith”*

In order to describe the Act, the following table (Table 6-4) is a summary of the pertinent terms and their explanations as they are applicable to the Act (quoted from Section 1 of the Act).

**Table 6-4: Definitions pertaining to the National Nuclear Regulator Act (47/1999)**

Term	Explanation
action	(a) the use, possession, production, storage, enrichment, processing, reprocessing, conveying or disposal of, or causing to be conveyed, radioactive material
	(b) any action, the performance of which may result in persons accumulating a radiation dose resulting from exposure to ionizing radiation
	(c) any other action involving radioactive material
closure	the completion of all operations after the emplacement of spent fuel or radioactive waste in a disposal facility
nuclear accident	any occurrence or succession of occurrences having the same origin which
	(a) results in the release of radioactive material, or a radiation dose, which exceeds the safety standards contemplated in section 36
	(b) is capable of causing nuclear damage
nuclear authorization	a nuclear installation license, nuclear vessel license, certificate of registration or certificate of exemption
nuclear damage	(a) any injury to or the death or any sickness or disease of a person
	(b) other damage, including any damage to or any loss of use of property or damage to the environment
	which arises out of, or results from, or is attributable to, the ionizing radiation associated with a nuclear installation, nuclear vessel or action
nuclear incident	(a) any unintended event at a nuclear installation which causes off-site public exposure of the order of at least one tenth of the prescribed limits
	(b) the spread of radioactive contamination on a site or exposure of a worker above the prescribed limits or a significant failure in safety provisions, other than a nuclear accident
nuclear installation	(a) a facility, installation, plant or structure designed or adapted for or which may involve the carrying out of any process, other than the mining

	and processing of ore, within the nuclear fuel cycle involving radioactive material, including, but not limited to
	(i) a uranium or thorium refinement or conversion facility;
	(ii) a uranium enrichment facility;
	(iii) a nuclear fuel fabrication facility;
	(iv) a nuclear reactor, including a nuclear fission reactor or any other facility intended to create nuclear fusion;
	(v) a spent nuclear fuel reprocessing facility;
	(vi) a spent nuclear fuel storage facility;
	(vii) an enriched uranium processing and storage facility; and
	(viii) a facility specifically designed to handle, treat, condition, temporarily store or permanently dispose of any radioactive material, which is intended to be disposed of as waste material; or
	(b) any facility, installation, plant or structure declared to be a nuclear installation in terms of section 2(3);
plant	any machinery, equipment or device, whether it is attached to the ground or not
radioactive material	any substance consisting of, or containing, any radioactive nuclide, whether natural or artificial, including, but not limited to, radioactive waste and spent nuclear fuel
radioactivity	the measure of a quantity of radioactive materials

Section 2 of the National Nuclear Regulator (NNR) Act gives the application of the Act as well as declaration of a nuclear installation. As quoted from the Act, these are:

(1) *“Subject to subsection (2), this Act applies to:*

- (a) the siting, design, construction, operation, decontamination, decommissioning and closure of any nuclear installation*
- (b) vessels propelled by nuclear power or having radioactive material on board which is capable of causing nuclear damage; and*
- (c) any action which is capable of causing nuclear damage.*

(2) *This Act does not apply to:*

- (a) exposure to cosmic radiation or to potassium-40 in the body or any other radioactive material or actions not amenable to regulatory control as determined by the Minister, after consultation with the board and by notice in the Gazette;*
- (b) subject to section 41(4), any action where the radioactivity concentrations of individual radioactive nuclides, or the total radioactivity content, are below the exclusion levels provided for in the safety standards contemplated in section 36;*

- (c) *Group IV hazardous substances as defined in section 1 of the Hazardous Substances Act, 1973 (Act No. 15 of 1973);*
- (d) *exposure to ionizing radiation emitted from equipment, declared to be a Group III hazardous substance in terms of section 2 (1) (b) of the Hazardous Substances Act, 1973.*

(3) *For the purposes of this Act, the Minister may, after consultation with the board and by notice in the Gazette, declare any facility, installation, plant or structure, including a mine or ore-processing facility, to be a nuclear installation.”*

The Act establishes the NNR as regulatory authority regarding these actions such that the objectives of the NNR, as quoted from section 5 of the Act, are to:

- (a) *“provide for the protection of persons, property and the environment against nuclear damage through the establishment of safety standards and regulatory practices;*
- (b) *exercise regulatory control related to safety over*
  - i. *the siting, design, construction, operation, manufacture of component parts, and decontamination, decommissioning and closure of nuclear installations; and*
  - ii. *vessels propelled by nuclear power or having radioactive material on board which is capable of causing nuclear damage, through the granting of nuclear authorisations;*
- (c) *exercise regulatory control over other actions, to which this Act applies, through the granting of nuclear authorisations;*
- (d) *provide assurance of compliance with the conditions of nuclear authorisations through the implementation of a system of compliance inspections;*
- (e) *fulfil national obligations in respect of international legal instruments concerning nuclear safety; and*
- (f) *ensure that provisions for nuclear emergency planning are in place.”*

Moreover, section 20 of the Act gives restrictions on certain actions such that they require nuclear authorization from the NNR, these, as quoted from the Act, are:

- (1) *"No person may site, construct, operate, decontaminate or decommission a nuclear installation, except under the authority of a nuclear installation license.*
- (2) *No vessel which is propelled by nuclear power or which has on board any radioactive material capable of causing nuclear damage may*
  - (a) *anchor or sojourn in the territorial waters of the Republic; or*
  - (b) *enter any port of the Republic**except under the authority of a nuclear vessel license.*
- (3) *No person may engage in any action described in section 2 (1) (c) other than any action contemplated in subsection (1) or (2), except under the authority of a certificate of registration or a certificate of exemption."*

In light of this information, with exception to the acquisition of nuclear related equipment and material that is regulated by the Nuclear Energy Act (Act No. 46 of 1999), the NNR will regulate almost all actions involved with the nuclear plant. Furthermore, the NNR may justifiably be a regulatory authority regarding chemical plant operation. This is due to the chemical plant essentially performing a similar function than the electricity generating section of electricity dedicated nuclear power plants, which is the removal of heat from the primary system of the nuclear plant. Regardless of the ultimate objective of this heat removal, electricity generation as opposed to process heat application, they perform a similar function with respect to the operation of the nuclear plant. However, process heat dedicated nuclear plants will in all likelihood employ an IHX to isolate the nuclear cycle from the chemical production cycle, whereas in electricity dedicated nuclear plants the electricity generating section is directly coupled with the nuclear cycle. Even though the use of an IHX in combination with the physical separation of the nuclear and chemical facilities increases the degree of isolation of the facilities, it is unlikely that the chemical facility will be entirely absolved from the NNR Act. It will certainly be an important aspect during licensing of the nuclear plant, thereby making it subject to thorough investigation by the regulatory authority, which according to this Act is the NNR. To this extent, sections 21 and 22 of the Act involve specifics regarding applications for nuclear installations or vessel licenses and certificates of registration or exemption for certain actions. Additionally, section 23 gives conditions relating to nuclear installation license, nuclear vessel license or certificate of registration, which, as quoted from the Act, are:



- (1) *"The chief executive officer may establish standard conditions applicable to one or more categories of certificates of registration.*
- (2) *The chief executive officer may, subject to subsection 3, impose any condition in a nuclear installation or vessel license or certificate of registration which*
  - (a) *is necessary to ensure the protection of persons, property and the environment against nuclear damage; or*
  - (b) *provides for the rehabilitation of the site.*
- (3) *The chief executive officer -*
  - (a) *may, subject to paragraph (c), amend any condition in a nuclear installation or vessel license or certificate of registration;*
  - (b) *must notify the person in writing to whom the nuclear installation or vessel license or certificate of registration was issued of such amendment and the reasons there for; and*
  - (c) *must submit to the board any amendments made to a nuclear authorisation as contemplated in paragraph (a) for ratification at the first meeting of the board following the amendments."*

In this regard, the perceived safety of combining and co-locating the nuclear and chemical facilities will play a vital role during licensing applications and will probably be subject to the opinion of the CEO and licensing panel, which may not exclusively be based on the actual safety associated with the technology. Similarly, public opinion regarding the perceived safety of the complex is also of paramount importance due to the political consequences that implementation of the technology may have. Nuclear Energy is and has historically been a sensitive political issue, probably more so in the US and Europe than in South Africa, and requires skilful managing and alleviation of the concerns associated with it. Especially with regard to public acceptance since the public's concern regarding nuclear energy may stem from a lack of knowledge and (to some extent) almost irrational fear of a Chernobyl-type of disaster to occur. The severe consequences of this accident justifies the public's fear and concern, however, post-Chernobyl there have been significant advances in nuclear technology and regulations that make it very improbable that a similar event could occur. It is the responsibility of the nuclear industry to alleviate these concerns by "proving" and promoting safety of the technology, as well as to provide relevant information to "educate" those that require it. However, universal acceptance of nuclear energy will never be achieved. There will always be those who ardently oppose it, regardless of the benefits thereof or the dangers associated with the alternative energy sources. All energy options have disadvantages that range

from economical feasibility to hazards associated with some part of the life cycle of the technology (mining, manufacturing, construction, operation, waste disposal and decommissioning).

Chapter 5 of the NNR Act is concerned with the safety and emergency measures of nuclear installations or other facilities or vessels regulated by the NNR. With regard to safety measures, section 36 allows for safety standards and regulatory practices such that:

- (1) *"The Minister must, on the recommendation of the board, make regulations regarding safety standards and regulatory practices.*
- (2) *Before any regulations are made in terms of subsection (1), the Minister must, by notice in the Gazette, invite the public to comment on the proposed regulations and consider that comment."*

In accordance with section 36, the Minister of Minerals and Energy, by notice in the Government Gazette of 28 April 2006, established regulations (R. 388) regarding safety standards and regulatory practices associated with nuclear activities that are subject to the NNR Act (Act No. 47 of 1999; GG, 2006). According to section 2.1.1.1(a) and 2.1.1.2 of R. 388, the actions associated with the chemical facility may be excluded from regulatory control if the activities of the radioactive components in all process streams are below 0.2 Bq/g or the level of total radioactivity is below 1000 Bq. With respect to these regulations the chemical facility will be subject to regulatory control due to the product having a radioactivity of approximately 12 Bq/g and total radioactivity well above 1000 Bq (12 Bq/g multiplied by the amount stored onsite  $\approx$  172 tonnes for a production of 2 kg hydrogen per second and assuming 1 day's production stored onsite). Similarly, according to section 2.2.2 of R. 388 the chemical facility does not qualify for exemption without further consideration. However, section 2.2.3 of R. 388 allows for exemption with further consideration, which is:

*"subject to a case-by-case evaluation by the regulator based on the specific radioactivity, the total radioactivity of discrete radioactive nuclides or on exposure scenarios"*

This route to exemption may be possible due to tritium being the only radioactive nuclide present in the process section and would have been exempted by section 2.2.1.3 if less than 1 tonne was produced per year. This is due to radioactivity

concentrations and total radioactivity content at the chemical plant being within the allowable limits (see Table 6-5), but exceeding the limitation of 1 tonne per year being produced (if the SMR process is to be used, natural gas has a naturally occurring radioactive content that will require its inclusion in radioactive calculations).

**Table 6-5: Exempt radioactivity concentrations and exempt total radioactivity content**

Nuclide	Radioactive Concentration (Bq/g)	Total Radioactivity Content (Bq)
H-3 (Tritium)	1.00E+06	1.00E+09

However, if exemption is not obtained, subject to sections 22 and 23 of the NNR Act (Act No. 47 of 1999) and according to section 2.3 of R. 388, the chemical facility requires to be registered if it is not considered part of the nuclear installation or a nuclear vessel.

In order to qualify for registration or to obtain a nuclear installation or nuclear vessel license, the dose limit to individuals must not exceed the values given in Table 6-2 during normal operation. Furthermore, the risk of fatality from any action as defined in the NNR Act (Act No. 47 of 1999) must not exceed the values given in Table 6-6, as stated in section 3.1 of R. 388 and given in Annexure 2 and 3.

**Table 6-6: Probabilistic risk limits (R. 388)**

<b>Public</b>	
Average annual population risk	10 <sup>-8</sup> fatalities per year per site
Maximum annual individual risk	5E-6 fatalities per year
<b>Workers</b>	
Average annual risk to workers	10 <sup>-5</sup> fatalities per year per site
Maximum annual individual risk to workers	5E-5 fatalities per year per site

The remaining sections (37 - 41) of Chapter 5 of the NNR Act (Act No. 47 of 1999) are related to the following:

37. Duties regarding nuclear accidents and incidents
38. Emergency planning
39. Record of nuclear installations
40. Record of nuclear accidents and incidents and access thereto
41. Appointment and powers of inspectors

With respect to the study at hand, section 38 is relevant and finds application due to section 38(4), which is:

*“The Minister may, on recommendation of the board and in consultation with the relevant municipalities, make regulations on the development surrounding any nuclear installation to ensure the effective implementation of any applicable emergency plan.”*

The importance of this subsection lies in whether the chemical production facility is deemed part of the nuclear installation or if it is considered a separate facility. If it is the latter, the chemical facility need to adhere to section 38(4). In accordance therewith, the Minister of Minerals and Energy, by notice in the Government Gazette of 5 March 2004, incorporated regulation no. 287 into the NNR Act (Act No. 47 of 1999). Sections 3 and 4(a) of R. 287 are of importance and, as quoted from the regulation, are (GG, 2004):

3. *“The Regulator shall lay down, where appropriate, specific requirements relating to the control and/or monitoring of development within the formal emergency planning zone surrounding a specific nuclear installation, after consultation with the relevant provincial and/or municipal authorities.*
4. *The relevant provincial and/or municipal authorities must –*
  - (a) *develop and implement processes, based on the requirements contemplated in section 3, including associated acceptance criteria, for the conduct of periodic assessment of*
    - i. *current and planned population distribution;*
    - ii. *disaster management infrastructure; and*
    - iii. *new development,*

*to ensure that the emergency plan, as contemplated in section 38 of the (NNR) Act, can be implemented effectively at all times”*

Therefore, regardless of the chemical facility being part of the nuclear installation or a separate facility, it will be subject to scrutinizing by the NNR. However, the goal of determining if the chemical facility is part of the nuclear installation is to establish according to which regulations (chemical or nuclear) it will have to adhere. In light of the NNR Act, it will most probably fall under the jurisdiction of the NNR due to it being coupled to the nuclear reactor as well as due to it removing heat from the primary system of the nuclear reactor. Co-location on the nuclear island and locating it

adjacent to the nuclear island also make it subject to investigation by the NNR. Therefore, in all possible (thermochemical) scenarios it will to a varying degree be governed by the NNR. In this regard, it will be the industry's responsibility to convince the NNR of the chemical plant's safety such that it may be constructed and operated according to chemical plant regulations.

As a last point of interest, section 7(f) of the Act allows the NNR to regulate the transport of radioactive material, which is a very important topic under discussion worldwide. However, since the hydrogen product will not be considered a radioactive substance, or at most be considered a Group IV hazardous substance, the transport thereof will not be regulated by the NNR. In the extremely unlikely circumstance of it being a Group-IV hazardous substance, actions involving the product will be regulated by the DOH and not subject (under current law) to any nuclear related Acts (reference: Hazardous Substances Act, Act No. 15 of 1973). However, the transport of radioactive material (irradiated nuclear fuel and equipment) to and from the nuclear plant falls under the jurisdiction of the NNR and will be performed according to international principles as determined by the IAEA's Regulations for the Safe Transport of Radioactive Material.

#### **6.2.4 NNR REQUIREMENT- AND LICENSING DOCUMENTS**

Each nuclear reactor in South Africa is licensed by the NNR on a case-by-case basis, during which requirement documents (RD) and license documents (LD) are created according to which the nuclear plant operations should adhere to. The licensing process of the PBMR, and therefore any process heat application facility connected to the PBMR, is at a relatively early stage of development, especially with regard to aspects that may be of concern to nuclear-hydrogen production technologies. After consulting with both the NNR and PBMR licensing department, nuclear-hydrogen initiatives appear to be far beyond the current stage of the licensing process. Therefore, the regulatory aspects to be evaluated in this investigation are limited to the regulations contained in the Nuclear Energy Act (Act No. 46 of 1999) and the National Nuclear Regulator Act (Act No. 47 of 1999). From these Acts it seems probable that a nuclear/chemical complex could be licensed if it adheres to the dose limits (Table 6-2) and probabilistic risk limits (Table 6-6) contained in the NNR Act. Although all regulations need to be adhered to, these may be the most crucial during the licensing process. As stated in the introduction of this chapter, for the purposes of the investigation it is assumed that the HTGR plant is regulatory approved, which

may not be the case for several years. Regardless, the licensing process of a HTGR in South Africa is not at a stage where it can be evaluated with regard to being encouraging or a barrier to future developments in nuclear-assisted hydrogen technologies. However, the relative early stage of the licensing process need not be discouraging since the nuclear-hydrogen industry can be involved with the licensing process from the start and address licensing issues as they arise. It can be a concomitant effort by industry and the regulatory authorities to develop and implement regulations that are efficient and applicable to the technology while keeping the interests of both parties at heart.

### **6.2.5 SECONDARY ACTS AND REGULATIONS**

Secondary acts and regulations refer to regulatory aspects that were not considered in the preceding sections but which influence the licensing and operation of a nuclear/chemical complex. Among these regulations are the following:

- Air Quality Act (Act No. 39 of 2004)
- Atmospheric Pollution Prevention Act (Act No. 45 of 1965)
- Disaster Management Act (Act No. 57 of 2002)
- Electricity Act (Act No. 41 of 1987)
- Electricity Regulation Act (Act No. 4 of 2006)
- Environmental Conservation Act (Act No. 73 of 1989)
- Mine Health and Safety Act (Act No. 29 of 1996)
- Mineral and Petroleum Resources Development Act (Act No. 28 of 2002)
- National Building Regulations and Building Standards Act (No. 103 of 1977)
- National Environmental Management Act (Act No. 107 of 1998)
- National Water Act (Act No. 36 of 1998)
- Occupational Health and Safety Act (Act No. 85 of 1993)
- Physical Planning Act (Act No. 125 of 1991)
- Promotion of Access to Information Act (Act 2 of 2000)
- Local, Municipal and Provincial Legislation
- International Treaties regarding Nuclear Energy
- Other regulations regarding the environment, humans, resources and siting of nuclear plants

These (and other applicable) Acts and regulations need to be adhered to if a nuclear-hydrogen production facility is to be licensed, constructed and operated in South Africa. Absent from this list is the requirement and licensing documents (RD and LD series) required by the NNR to “approve” or license the technology.

### **6.3 INTERNATIONAL REGULATORY REQUIREMENTS**

In Chapter 5, the US Regulations that might be problematic during licensing of the combined complex were discussed according to the investigation performed by Smith *et al.* (2005). Since these regulations are extensively discussed in that chapter, only a short summary thereof is given now. Smith *et al.* (2005) identified three regulations that will be of major concern during licensing and implementation of nuclear-assisted hydrogen production facilities, these are risk-informed applications (RG 1.174), habitability of the nuclear plant control rooms (RG 1.78) and quantity distance relationships regarding flammable substances (RG 1.91). From RG 1.174 it is clear that if the hydrogen production facility results in an increase in CDF in excess of  $10^{-6}/\text{yr}$ , the regulating authorities will significantly scrutinize it. Considering RG 1.78, the nuclear plant control room should be adequately protected from flammable and hazardous chemical substances by locating it a sufficient distance away from these substances. However, the separation distance according to RG 1.91 is significantly greater than that required by RG 1.78 and will therefore be more influential in the process of licensing the nuclear/chemical complex.

In the EU, the main regulations, in this case directives, associated with the use and production of hydrogen are the Seveso Directives I and II. The Seveso Directive II allows for the control of major-accident hazards involving dangerous substances, with special relevance to the environment and quantities of hazardous materials (Vitart *et al.*, 2008), and is such that hydrogen has stricter quantity regulations than any other ordinary fuel (Rigas & Sklavounos, 2005). According to Piera *et al.* (2006), these Directives would have to be revised in order to obtain permission for constructing and operating a combined nuclear/chemical industrial complex.

### **6.4 CONCLUDING REMARKS**

It is clear that licensing of the combined complex will be extensive and may prove to be a significant barrier to the implementation of the technology. Most regulatory

authorities will have to review their regulations in order to make them applicable to the nuclear production of hydrogen via HTGR technologies. However, a concomitant effort by the industry and regulatory authorities are required if these technologies are to be successfully implemented.