SOCIO-ECONOMIC ANALYSIS

(non-confidential version)

Legal name of applicant: *LANXESS Elastomers B.V.*

Submitted by: *LANXESS Elastomers B.V.*

Substance: *Sodium dichromate*

CAS No. 10588-01-9 (anhydrous)

CAS No. 7789-12-0 (dihydrate)

EC No. 234-190-3

Use title: *Use of sodium dichromate as corrosion inhibitor in ammonia absorption deep cooling systems*

Use number: *1*

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DECLARATION

We, LANXESS Elastomers B.V., request that the information blanked out in the "public version" of the Socio-Economic Analysis is not disclosed. We hereby declare that, to the best of our knowledge as of today (10 November 2015) the information is not publicly available, and in accordance with the due measures of protection that we have implemented, a member of the public should not be able to obtain access to this information without our consent or that of the third party whose commercial interests are at stake.

Signature:

Date, Place: 10-11-2015

Christian Widdershoven,

CEO LANXESS Elastomers B.V.

Geleen, the Netherlands

LIST OF ABBREVIATIONS

µg	Microgram
AADC	Ammonia Absorption Deep Cooling
AfA	Application for Authorisation
AoA	Analysis of Alternatives
ACE	Advanced Catalyst Elastomer
CAGR	Compound Annual Growth Rate
Cr(VI)	Hexavalent chromium
CSR	Chemical Safety Report
DCPD	Dicyclopentadiene
EC	European Commission
ECHA	European Chemicals Agency
EEA	European Economic Area
ELR	Excess Lifetime Risk
ENB	Ethyldiene norbornene
EPDM	Ethylene-Propylene Diene M-rubber
EPT	Ethylene-Propylene Terpolymer
ES	Exposure Scenario
ETESS consortium	Expert Team providing Scientific Support for ECHA
EU	European Union
EUROSTAT	Statistical office of the European Union
GDP	Gross Domestic Product
GWh	Gigawatt hour
IARC	International Agency for Research on Cancer
LANXESS	LANXESS Elastomers B.V.
m^3	Cubic metre
MvE	Man via Environment
MvE local inhalation	Man via environment, local inhalation exposure
MvE local oral	Man via environment, local oral exposure
MvE regional inhalation	Man via environment, regional inhalation exposure
MvE regional inhalation	Man via environment, regional oral exposure
MWh	Megawatt hour
NewExt	New Elements for the Assessment of External Costs from Energy Technologies
NL	The Netherlands
NPV	Net Present Value
NUS	Non-Use Scenario
OEM	Original Equipment Manufacturer

PEC	Predicted Environmental Concentration
PVC	Polyvinyl Chloride
RAC	Committee Risk Assessment
RCR	Risk Characterisation Ratio
SEA	Socio-Economic Analysis
SEAC	Committee Socio-Economic Analysis
SVHC	Substance of Very High Concern
TWA	Time Weighted Average
VCC	Vapour Compression Cooling
VSCC	Value for a Statistical Case of Cancer
VSL	Value of Statistical Life
WCS	Worker Contributing Scenario
WTP	Willingness to Pay
w/w	Weight by weight

1. SUMMARY OF SOCIO-ECONOMIC ANALYSIS

This Socio-Economic Analysis (SEA) has been performed for the use of sodium dichromate as corrosion inhibitor in the Ammonia Absorption Deep Cooling (AADC) systems for the production of Ethylene-Propylene Diene M-rubber (EPDM**)** at the LANXESS Elastomers B.V. (LANXESS) site in Geleen, the Netherlands. EPDM is a type of synthetic rubber largely used by the automotive and construction sectors.

For the purpose of this SEA, a time frame of 20 years after the sunset date (review period) is assessed. The review period of 20 years was selected because it coincides with the remaining lifetime of the equipment which will have to be replaced in the Non-Use Scenarios (NUSs).

The outcomes of this SEA are briefly summarised in the following.

Monetised benefits to human health of a non-granted authorisation:

- **EUR 1 421** including potential health impacts to workers and the general population (see Section 7.1).[1] This value is based on absolute worst-case estimates (see ANNEX A).

For the investigation a methodology has been used that is described in the ECHA guidance on the preparation of socio-economic analysis as part of an application for authorisation, version 1, January 2011 (1) and the reference dose response relationship for carcinogenicity of hexavalent chromium substances agreed on at the 22nd meeting of the Committee for Risk Assessment (RAC) in September 2012 (2). The data for the assessment have been collected directly at different departments of LANXESS. Exposure data were taken from the corresponding Chemical Safety Report (CSR) (3). The outcomes of the respective Analysis of Alternatives (AoA) were considered when defining the NUSs (4).

Socio-economic impacts of a non-granted authorisation:

<u>NUS 1 - Replacement (change) of the cooling system:</u>

- Net economic impacts related to the investment, savings with new technology, loss of production capacity and downtime amounting to approx. **EUR** [redacted] (see Section 7.2.1)

<u>NUS 2 - Replacement of corrosion prone parts:</u>

- Net economic impacts related to new investment and downtime needed to replace parts of the cooling systems amounting to approx. **EUR** [redacted] (see Section 7.2.2)

Referring to the figures above, the benefits of a continued use of sodium dichromate as corrosion inhibitor AADC systems clearly outweigh the risks to human health and the environment (see summary table of the impact assessment in Section 8.1).

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[1] This equals one statistical cancer case in 40 000 (!) years of use of the substance under prevalent use conditions at the LANXESS site in Geleen (NL).

Uncertainties and potential variations are investigated in Section 8.2 concluding that the result is stable and defines an overestimation of health impacts to be expected.

In the light of recent developments regarding the inclusion of the business division concerned in this AfA in a joint venture announced by the LANXESS Group and Saudi Aramco on 22 September 2015 (LANXESS, 2015), it is important to emphasize that the merger will not have any influence on the situation regarding alternatives nor the impacts described in this SEA.

Apart from the outcomes of the quantitative impact assessment conducted in this SEA, it should be considered that LANXESS would suffer losses of competitiveness and market shares due to the forced downtime and reduction of production capacity when replacing the cooling systems. These impacts could not be quantified but are described qualitatively in Section 7.2.1 of this document.

Considering all factors elaborated in this SEA, a review period of 20 years is clearly justified.

2. AIM AND SCOPE OF SOCIO-ECONOMIC ANALYSIS

2.1. Aim

Sodium dichromate ($Na_2Cr_2O_7$) has been identified as a Substance of Very High Concern (SVHC) (according to Article 57(a) of Regulation (EC) No 1907/2006 (REACH) (5). Due to its intrinsic properties as being carcinogenic (Carc. 1B), mutagenic (Muta. 1B) and toxic to reproduction (Repr. 1B) sodium dichromate has been included into Annex XIV of REACH, making an Application for Authorisation (AfA) necessary to continue use of sodium dichromate in the European Union after the sunset date in September 2017. Furthermore, with respect to carcinogenicity and mutagenicity sodium dichromate is categorised as a non-threshold substance and therefore an AfA via the so-called Socio-Economic Analysis (SEA) route is foreseen under REACH (6).

This SEA forms part of the AfA for the use of sodium dichromate as corrosion inhibitor in Ammonia Absorption Deep Cooling (AADC) systems required for the production of Ethylene-Propylene Diene M-rubber (EPDM**)** at LANXESS Elastomers B.V. (LANXESS) production site in the industrial complex of the Chemelot industrial complex in Geleen, the Netherlands (NL). Other documents prepared as part of the AfA include a Chemical Safety Report (CSR) and an Analysis of Alternatives (AoA). These documents are referenced here to provide context for the SEA.

The aim of this SEA is to demonstrate that the socio-economic benefits associated with the continued use of sodium dichromate by the applicant outweigh the remaining risks to human health and the environment associated with prevalent use conditions (see Section 3).

2.2. Scope

The applicant LANXESS is a leading global manufacturer of high quality EPDM, which is supplied to and used in a range of industries such as automotive and building and construction. Sodium dichromate is used in the EPDM production process as a corrosion inhibitor in the AADC systems.

Since the polymerisation reaction of EPDM is highly exothermic, the heat of reaction needs to be removed from the system by means of pre-cooling of the reactor feed. This relevant step in the production process is achieved by the use of AADC systems. However, the ‘cooling medium’ (ammonia water mixture) which circulates in the system can provoke severe corrosion of the steel the cooling system is made of. Therefore, in order to create and maintain a protective layer against corrosion between steel and water, sodium dichromate is dosed into the system (see Section 3 for further details).

The scope of this analysis concentrates on the territory of the European Economic Area (EEA).

For the purpose of this SEA, an assessment period of 20 years was defined since this is the remaining lifetime of the current AADC systems operated by LANXESS in Geleen (NL). Because the sunset date for sodium dichromate is in 2017, the period of time covered by the SEA runs from 2018 to 2037 (taking 2017 as a base year for calculations).

3. DEFINITION OF THE APPLIED FOR USE SCENARIO

LANXESS is a manufacturer of EPDM which is a terpolymer based on three monomers: ethylene, propylene and a non-conjugated diene ("polymer" simply being a synthetic substance composed of many repeated subunits, the "monomers") see **Figure 1.**

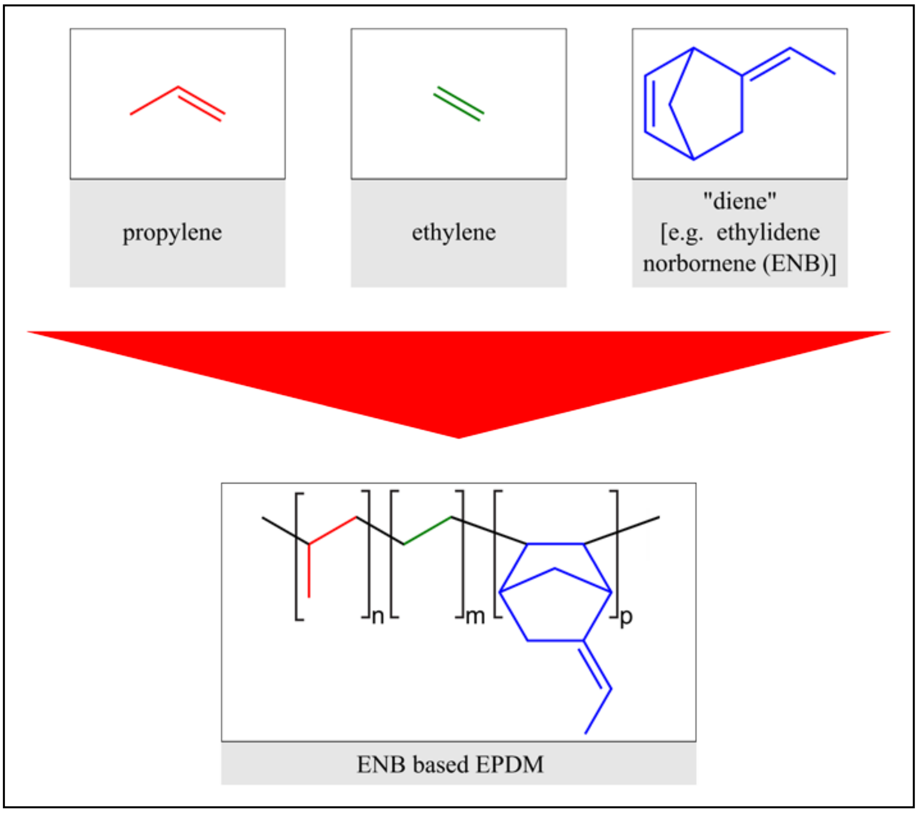


Figure 1: EPDM structure

3.1. EPDM applications and industries involved in the supply chain

The EPDM elastomers are mainly used in automotive and building and construction markets but also find their way into consumer goods like washing machine/dish washer seals and seals and hoses for potable water/food contact applications.

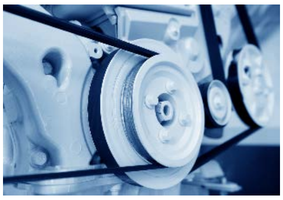
EPDM is largely used in rubber applications. In the automotive industry for instance in sealing systems (both solid and sponge) as well as in radiator hoses and gaskets. In the building and construction sector, EPDM plays an important role in meeting the demanding requirements of the window glazing segment. LANXESS is also a valued supplier to non-rubber segments such as plastics modification (thermoplastic vulcanisates) and petroleum additives as well as to more critical applications, like brake systems, food contact materials and potable water applications. See Table 1 for a full list of applications including exemplary pictures (7).

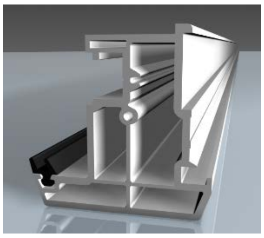
Table 1: List of EPDM applications

Industries / applications	Products

Automotive sector


	• Sealing systems
	  o Soft sponge extruded profile
	  o Solid extruded profile
	• Dashboard parts
	• Hoses
	• V-Belts
	• Anti-vibration parts
	• Brake systems

Mechanical rubber goods   	• Washing machine gaskets (bull-eyes) • Potable & waste water seals • Valve and tank linings • Roll coverings • Hoses and tubes • Conveyor belts • Floor tiles

Industries / applications	Products
Building and Construction    	• Window profiles • Seals for water applications • Sheets / roofing / linings • Others including tunnel seals, sound insulation wall panels, artificial grass
Plastic modification 	• Bumpers • Air bag covers • Automotive Sealing System • Air induction tubes • Medical products • Sporting goods

Oil additives

	• Motor oil
	    o Automotive
	    o Heavy duty diesel
	    o Maritime
	• Lubricating greases
	• Industrial oil

Wires and cables 	• Low, medium and high voltage cables • Cable insulation • Transmission and distribution, such as connectors, arrestors, relays

3.2. EPDM production

The production process of EPDM at LANXESS is carried out in three Ethylene-Propylene Terpolymer (EPT) plants named EPT1, EPT2 and EPT3 at the Chemelot industrial complex in Geleen (NL). In this process the monomers (ethylene, propylene, and a third monomer) are dissolved in an inert solvent (hexanes) and continuously fed to polymerisation vessels where the polymerisation reaction takes place in the presence of catalysts. This reaction is highly exothermic, therefore a powerful pre-cooling system is necessary to remove the heat of reaction from the system (the reactor feed). In this sense, the cooling step is essential for the production process, since, without removal of the heat of reaction, the production capacity would decrease drastically: for EPT1 and EPT2 this would imply a capacity reduction of around 40%, for EPT3 a reduction of 60%. Additionally, the variable cost of the product would increase due to the higher specific energy consumption and less recycling efficiency of monomers.

The cooling is done by means of AADC systems, in which sodium dichromate is essential for corrosion protection. Each plant has its own AADC system. The installed production capacity for EPT1 and EPT2 is [redacted] tonnes each, while for EPT3 the production capacity is [redacted] tonnes. The cooling capacity (at -60^{o} C) for EPT1 and EPT2 is around [redacted] each and [redacted] for EPT3. The cooling system content (in terms of 'cooling medium') is [redacted] for EPT1 and EPT2, and [redacted] for EPT3.

The pre-cooling of the reactor feed by mean of an AADC system, where sodium dichromate is used is one of the first steps in LANXESS EPDM production, see **Figure 2.**

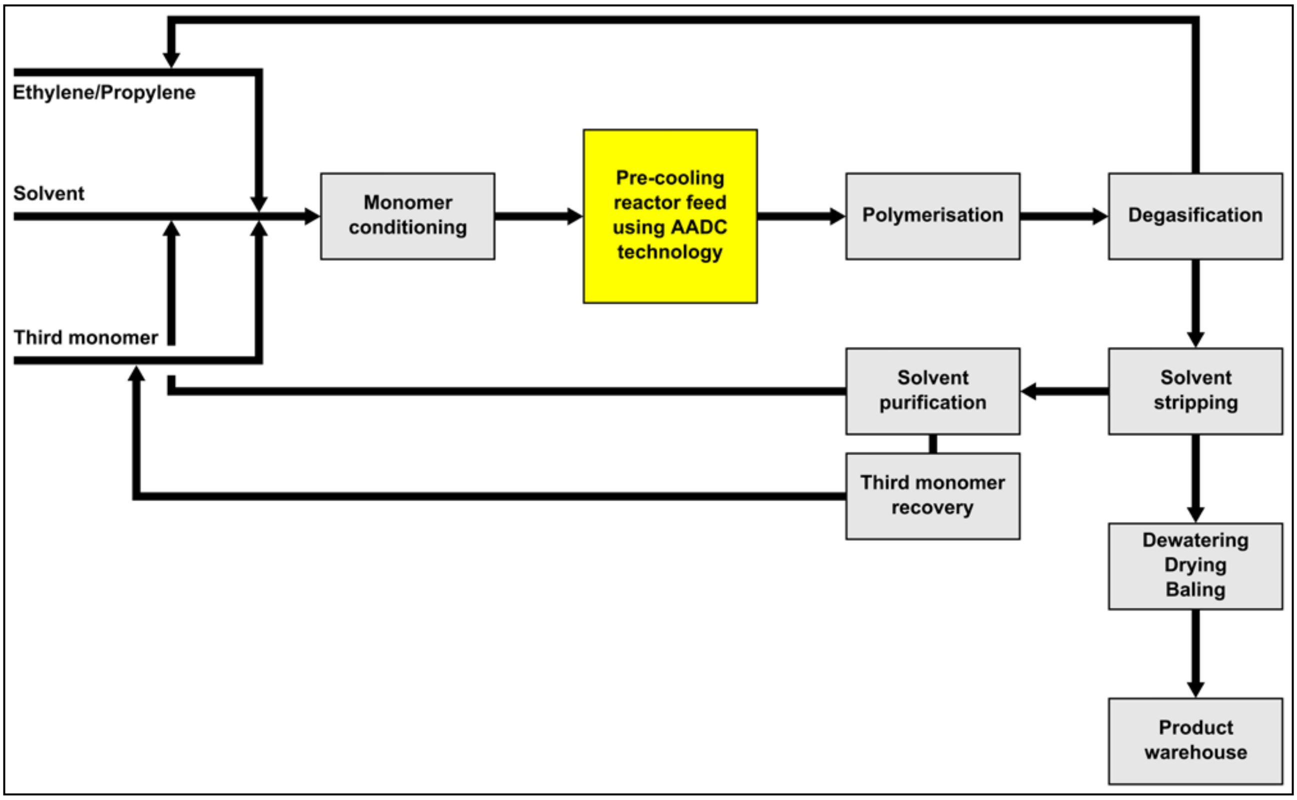


Figure 2: Simplified flow diagram of the LANXESS EPDM production process

3.3. Use of sodium dichromate in AADC systems

Each AADC system operating at the LANXESS sites in Geleen (NL) is designed as a closed system.

AADC systems are based on ammonia as a refrigerant, which is constantly circulating through the system to collect and disperse heat. By changing the state of the refrigerant, the temperature and the quantity of heat that is carried by the system also changes.

The main difference between a Vapour Compression Cooling (VCC) system and an absorption cooling system is the source of energy used to drive the process. VCC systems are usually driven by electrical energy, whereas absorption cooling systems such as the ones operated by LANXESS in Geleen (NL) make use of thermal energy [e.g. steam]. The following steps briefly describe how an AADC system works (see **Figure 3**). For further details on the LANXESS EPDM production process and the functioning of the cooling system, please consider the AoA (4).

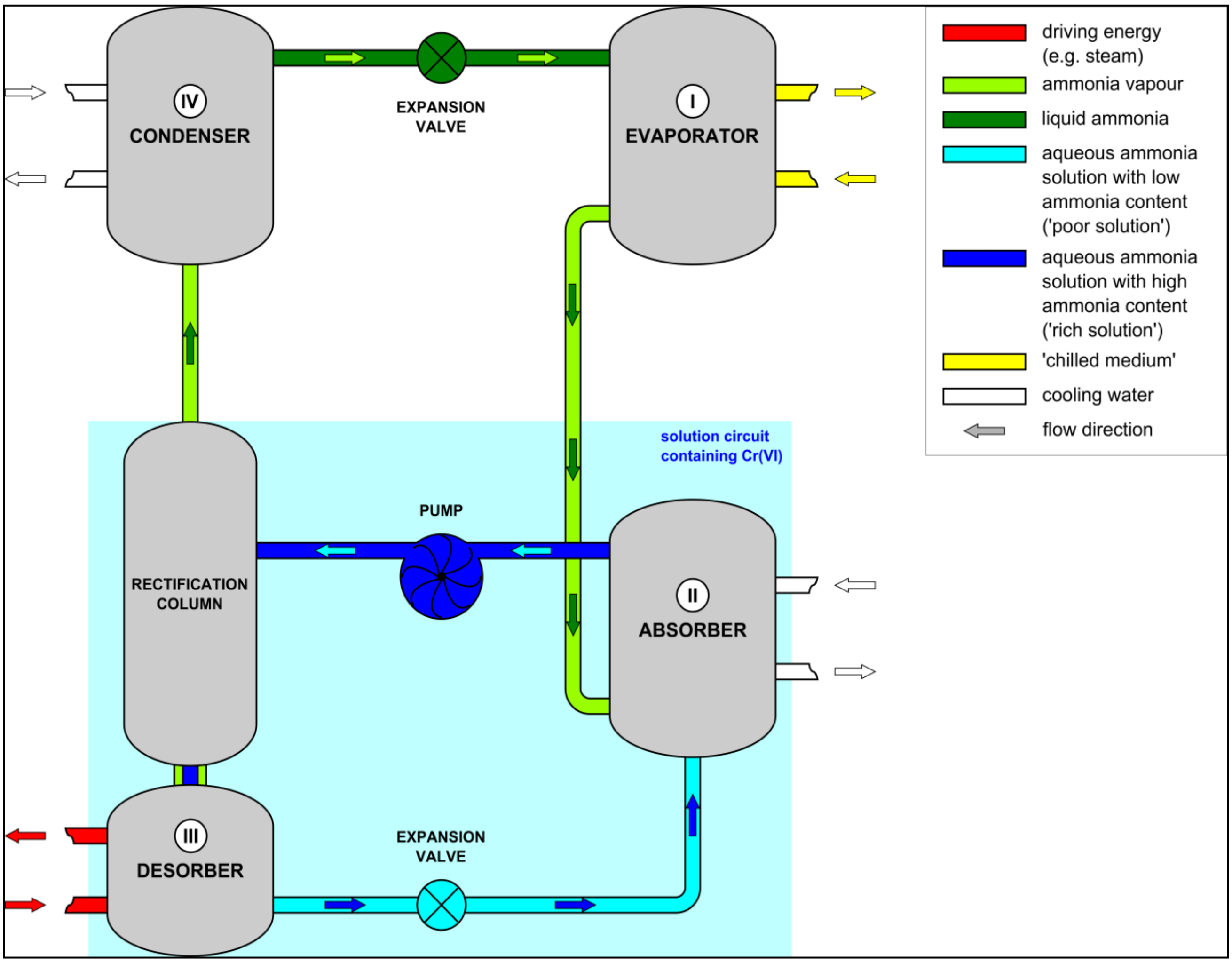


Figure 3: Simplified functional scheme of an AADC system

An AADC system allows to produce cold down to -60 °C using excess or waste heat as the main energy source ['driving energy' (e.g. steam)].

The ammonia absorption refrigeration process/cycle can be subdivided into the following four basic steps (see **Figure 3**).

Step 1:
In an **evaporator (I)** liquid ammonia is evaporated at low (sub-atmospheric) pressure by taking the required energy ('heat of evaporation') from the surrounding area. Upon which a liquid [e.g. reactor feed (monomers) for the LANXESS EPDM production] that is pumped through the evaporator in a separate circuit is cooled down ('chilled medium').

Step 2:
The ammonia vapour generated in Step 1 is transferred to an **absorber (II)**, where it is taken up (absorbed) by an aqueous ammonia solution with a low ammonia content ('poor solution') leading to an ammonia enriched solution ('rich solution'), which is fed to a **rectification column** that is connected to a **desorber (III)**.

Step 3:
By heating up in the **desorber (III)** the 'rich solution' generated in Step 2 is separated into 'poor solution', consisting mainly of water and 'vapour', consisting mainly of ammonia.

The 'poor solution' is sent back to the absorber to again absorbing ("used") ammonia vapour and producing a 'rich solution'. Whereas the 'vapour' is purified in the **rectification column** to result in nearly pure ammonia vapour.

Step 4:
The ammonia vapour generated in Step 3 is liquefied in a **condenser (IV)** and again fed into the evaporator.

3.3.1 Relevance of sodium dichromate

Sodium dichromate acts as corrosion inhibitor in order to create and maintain a protective layer (magnetite layer) between steel and the ‘cooling medium’ (ammonia water mixture). For each litre of ‘cooling medium’, approx. 5 g of sodium dichromate are used. In case of non-presence of sodium dichromate, a corrosion mechanism would take place as described below.

- Corrosion mechanism in the absence of oxygen:

$Fe + 2\ H_2O \rightarrow Fe(OH)_2 + H_2$

$3\ Fe(OH)_2 \rightarrow Fe_3O_4 + 2\ H_2O + H_2$

In order to not allow corrosion on steel, sodium dichromate is added and the following chemical reaction takes place creating a protective layer, see below:

$Na_2Cr_2O_7 + 2\ NaOH \rightarrow 2\ Na_2CrO_4$

$9\ Fe + 8\ Na_2CrO_4 \rightarrow 8\ H_2O \rightarrow 3\ Fe_3O_4 + 4\ Cr_2O_3 + 16\ NaOH$

When sodium dichromate is added, no hydrogen is formed.

In summary, the main essential and unique properties of sodium dichromate are:

- Good corrosion inhibition properties / in situ repair for the most critical conditions (medium, temperature, flow rates) in the ammonia absorption cooling system
- Prevention of formation of inert gases which would otherwise build up in the system

For further details on the properties of sodium dichromate in AADC systems please refer to the AoA (4).

3.3.2 Sampling and refilling of sodium dichromate

Considering the three cooling plants of LANXESS, in total less than 0.3 tonnes of sodium dichromate equivalent to 0.12 tonnes hexavalent chromium [Cr(VI)] are used per year.

Periodically (typically every 3 months), a sample is taken from the closed loop system. If the concentration of sodium dichromate is below the set point, extra sodium dichromate solution is dosed into the system in order to get the required concentration and protection level of the equipment. In this way the sodium dichromate concentration is used to monitor the integrity of the cooling system. Samples for analysis are taken from the 'poor solution' downstream in the desorber (pressure above atmospheric pressure). If needed, aqueous 60 % weight by weight (w/w) solution (delivered in drums) is added to the system by means of vacuum at the sub-atmospheric pressure side of the system, more specifically at the absorber.

3.3.3 Activities relevant for potential worker exposure to sodium dichromate

The following activities relevant for potential worker exposure to sodium dichromate were identified (see also CSR):

- Use of sodium dichromate as corrosion inhibitor in ammonia absorption deep cooling systems (PROC 1)
- Sampling cooling medium (PROC 9)
- Laboratory analysis of cooling medium (PROC 15)
- Concentration adjustment (addition of sodium dichromate solution to the cooling circuit) (PROC 8b)
- Maintenance (emptying, intermediate storage of the cooling medium and re-filling) (PROC 8b)

The monetized health impacts connected to these Worker Contributing Scenarios (WCSs) will be evaluated in Section 6.2 of this SEA. For details please refer to the CSR (3).

3.4. EPDM market information

Considering the European EPDM market, LANXESS' market share was estimated to be [redacted] in 2013. In the same year, LANXESS' share of the worldwide EPDM market reached 21%.

LANXESS sales are expected to grow due to the growth of the EPDM market. This market is expected to grow on a Compound Annual Growth Rate (CAGR) of 3.8% in the next 5 years. The main application growth is coming from the automotive market and plastic modification. China will be the biggest contributor for the global growth with a CAGR of 7%. European CAGR expectation is 2.5%. Consequently, LANXESS expects a steady growth of the EPDM market and production lines are expected to run at full capacity in the next years to come.

[redacted] (see Section 5 for further details).

3.5. Financial and employment data

LANXESS in Geleen (NL) generated EUR [redacted] in turnover in 2013, being more than EUR [redacted] related to the production of EPDM, which relies on proper functioning of the AADC systems.

Regarding expenditure with suppliers, considering the whole facility, EUR [redacted] were spent in 2013. Expenditure with energy for the whole facility in Geleen (NL) totalised EUR [redacted] in that year.

In 2013, [redacted] people were employed at the facility, being [redacted] of those employees with academic degree and [redacted] high skilled employees. Still considering that year, approximately EUR [redacted] were spent on salaries for the whole facility.

3.6. Past research regarding alternatives for the current technology

During the last years, LANXESS made considerable efforts to identify possible corrosion inhibitor alternatives. In the course of these efforts scientific literature was evaluated and experts from other companies and institutions concerned with corrosion were contacted.

In 2009, corrosion specialists from the LANXESS integrated Chemelot site in Geleen (NL) repeated a survey contacting experts in corrosion at other chemical companies however, no new insights could be gained. At the same opportunity contact was made with two suppliers of ammonia absorption installations and no proven alternatives were reported to be available.

In the beginning of 2015, a water technology/treatment company was invited to assess alternatives but unfortunately no alternative could be proposed. The AoA contains more information on the research on alternatives (4).

In the light of recent developments regarding the inclusion of the business division concerned in this AfA in a joint venture announced by the LANXESS Group and Saudi Aramco on 22 September 2015 (LANXESS, 2015), it is important to emphasize that the merger will not have any influence on the situation regarding alternatives.

4. DEFINITION OF THE NON-USE SCENARIOS

Considering the currently applied cooling technology for EPDM production at the LANXESS site in Geleen (NL) - AADC systems - the non-availability of sodium dichromate in the process would lead, within months, to failure of the equipment due to constant corrosion and, consequently, the need for drastically shortened maintenance intervals and exchange of corrosion prone parts. In this case it would be necessary to shut the concerned plant down for at least some weeks, (plants operate 24 hours/day, 7 days/week) in order to repair the damaged equipment and replace the piping system. Due to the lack of experience, the exact intervals cannot be stated here, but for obvious reasons the inspection and maintenance intervals need to be short enough to exclude ammonia release[2]. Clearly, the faster depreciation of the production equipment, the increased costs for repair and maintenance, the losses with downtime as well as the potential hazards with ammonia spilling make this an absolutely non-feasible scenario.

Due to the fact that the removal of reaction heat is a prerequisite for the production of EPDM and given that there are no alternative substances which could replace sodium dichromate, different cooling technologies have to be taken into account as theoretically possible Non-Use Scenarios (NUSs) for LANXESS (see **Figure 4**).

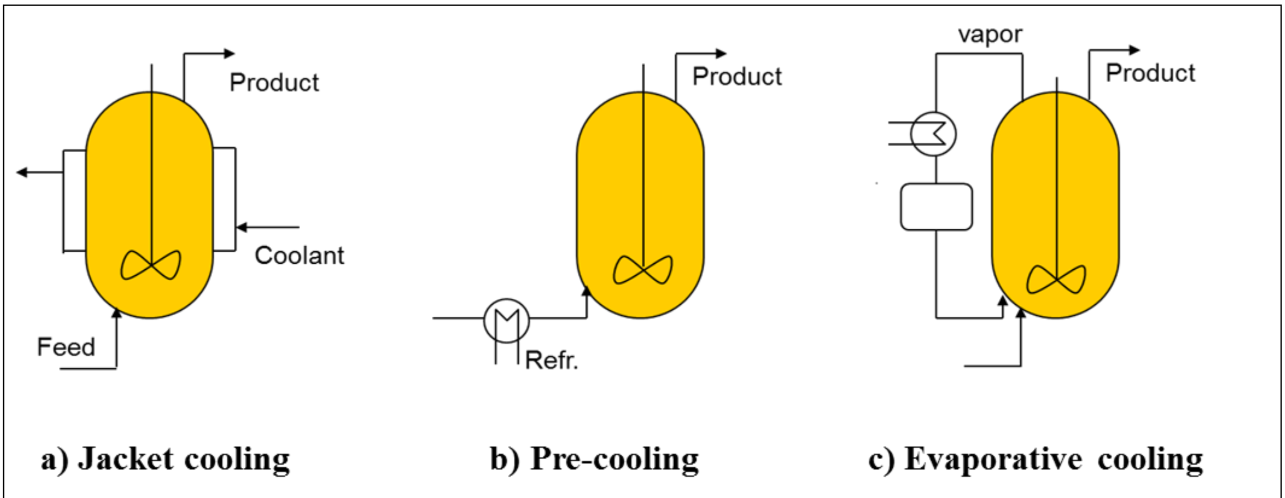


Figure 4: Schematic representation of cooling technologies

[2] In a worst case this could lead to accidents and the uncontrolled release of up to 100 % ammonia into the environment what would be a severe incident.

As depicted in **Figure 4**, in principle, the reaction heat can be removed with the following technologies:

a) Jacket cooling or internal cooling coils in the reactor

The reaction mixture is cooled with a cooling medium present in a jacket around the reactor wall or in cooling coils inside the reactor. However, the disadvantages of this technology are:

- Low effectiveness leading to fouling problems, especially for high viscous solutions as applied at the LANXESS production site in Geleen (NL).
- Requires a complete new reactor design since it is not suitable for the type of (large scale) reactors that are currently in use at the LANXESS production site in Geleen (NL).

Clearly, the investment costs as well as the downtime needed for the implementation of a complete new reactor system clearly make this option not a feasible non-use scenario.

b) Pre-cooling of reactor feed:

Pre-cooling of the reactor feed is the cooling technology currently applied at the LANXESS production site plants in Geleen (NL).

There are two different systems that can be used for pre-cooling of the reactor feed:

- AADC systems, which are currently operated by LANXESS in Geleen (NL)
- VCC systems

c) Evaporative cooling

The reaction heat is removed by evaporation of the reactants. The vapour is compressed, condensed and then recycled back into the reactor feed. Theoretically, this is an applicable cooling technology, but the implementation would cause inacceptable disadvantages, that make it a non-feasible option for LANXESS:

- The implementation requires a complete new design and process control of the reactor section. It would totally change the essence of the production process with the necessity of new reactors, process gas compressors and condensers.
- It would be possible to develop and produce “Performalike” products (items with the same properties as the ones currently produced using pre-cooling technology), but new customer approvals would still be required for many applications. Besides this, it would also require a redesign of LANXESS' pilot plant where products are tested on small scale for further development in large scale plants.

During the assessment of the different cooling technologies it became clear that the implementation of a jacket cooling / internal cooling (a) or evaporative cooling (b) would require major changes to the entire production process. Consequently, the investment costs for the exchange of the cooling system and the reactor equipment would be prohibitively high making these options unfeasible for LANXESS.

However, the replacement of the cooling system by a VCC system or the less favourable exchange of corrosion prone carbon steel parts to stainless steel are considered NUSs that would in theory be possible for LANXESS.

Therefore, these NUSs are described in the following and quantitatively investigated in Section 7.2 of this report.

4.1. NUS 1 - Replacement (change) of the cooling system

In order to stop the use of sodium dichromate, LANXESS could replace the current cooling system by a cooling system based on a different technology (e.g. vapour compression) which does not need sodium dichromate for corrosion protection.

The main difference between these two technologies is that in a VCC system, a compressor (typically) driven by electrical energy is used while the absorption cooling system uses thermal energy (heat) as driving energy. Further technical details regarding the two cooling technologies are provided in the AoA (4).

It is important to mention that, given the high uncertainties regarding the economic sustainability (or future profitability) of the operations due to the impacts to be mentioned later in this document (the most important of them being the loss of production capacity when using the new cooling system), this NUS can evolve to a more critical situation where the plants would have to be shut down. This is explained by the fact that in a business which is highly dependent on scale, the loss of production capacity is a critical factor to be taken into consideration when deciding to carry on with operations.

4.2. NUS 2 - Replacement of corrosion prone parts

The exchange of corrosion prone parts currently made of carbon steel by stainless steel or surface coated materials would in principle be a technically feasible scenario. Based on the current knowledge all equipment (heat exchangers, vessels, pumps, piping, and absorbers) in contact with 'cooling medium' (ammonia water mixture) would need to be replaced by stainless steel.

A manufacturer of absorption cooling units was requested to estimate costs for a possible exchange of the following components which are seen as critical to corrosion and should be exchanged:

Table 2: Costs for exchange of corrosion prone parts

Part	Costs [EUR]
Desorber	250 000
Solution heat exchanger	320 000
Absorber	250 000
Absorber	370 000
Absorber	370 000
Total	**1 560 000**

Note: These costs are to be seen per cooling system excluding labour costs for (de-)construction and project overhead costs.

However, industrial AADC systems have never been tested with stainless steel parts and therefore nothing is known about the lifetime of these systems. According to recent research, also no guarantee can be provided that a cooling system with stainless steel parts will work safely without sodium dichromate as corrosion inhibitor. Further technical information on this NUS can be found in the AoA (4).

Regardless of the huge uncertainties in this NUS, which in the end might make the NUS not viable, it will also be taken into account for the impact assessment.

In addition to the investment costs for the stainless steel parts, a downtime of production of at least [redacted] would be connected to this NUS and will be factored in in terms of value added foregone when assessing the impacts in Section 7 of this report.

5. INFORMATION FOR THE LENGTH OF THE REVIEW PERIOD

The equipment related to the EPDM production implemented at the LANXESS site in the Chemelot industrial complex in Geleen (NL) are long term investments which have a productive lifetime of decades. The cooling systems installed at the production plants EPT1, EPT2 and EPT3, from this moment, still have at least 20 years of remaining lifetime.

A relevant part of the current equipment has been modernised recently since LANXESS completed in 2013 an investment of EUR 12 million in the production site in Geleen (NL), converting 50 percent of the EPDM production capacity to the innovative Advanced Catalyst Elastomer (ACE) technology. The ACE technology allows considerable energy savings in comparison to conventional technologies as well as production of special types of EPDM (8).

Considering the fact that the currently installed cooling systems would still have more than 20 years of remaining lifetime, the investment in new cooling systems would bring forward an investment that would otherwise only happen in 20 years. Therefore and because of the lack of an alternative corrosion inhibitor which could be used instead of sodium dichromate, 20 years is the review period applied for in this SEA.

[redacted]

[redacted]

[redacted]

[redacted]

LANXESS inventory is typically sufficient to cover [redacted] sales. For special applications segment LANXESS may extend this through prioritisation to [redacted], but after maximum [redacted] these applications will run dry in the current situation. This means that automotive OEMs will have trouble getting EPDM based safety parts for at least [redacted] with issuance of a liability waiver and up to [redacted] without the issuance of liability waivers.

6. METHODOLOGY FOR IMPACT ASSESSMENT

An analysis of the monetised health impacts and socio-economic impacts is presented here to allow an evaluation of the benefits and risks related to the authorisation. The aim of this analysis is to support the findings of the qualitative description, where it has been concluded that the benefits of continued use of sodium dichromate would be substantial, while the remaining risks would be very well managed and very limited, following an authorisation. The analysis is built on and takes into account evidence gathered during the preparation of the CSR, AoA and SEA.

6.1. General approach

The SEA has been conducted in accordance with the approach set out in the ECHA guidance on the preparation of socio-economic analysis as part of an application for authorisation, version 1, January 2011 (ECHA guidance on SEA) (1). The reader is referred to the guidance for appropriate context and general information on the approach to the SEA, while more specific aspects relevant to this document are discussed below.

Specific data used for the analysis of impacts in the SEA at hand was gathered by the use of questionnaires sent to the responsible staff in the different departments of the company. In addition, a site visit at LANXESS provided supportive information to be able to reflect the on-site situation in the authorisation dossier. Additional benefits from the site visit were e.g. clarification of questions of details, discussion of NUS and maximisation of understanding of the use of sodium dichromate and the production processes.

As an underlying basis for the assessment of impacts in this SEA, the estimation of health impacts was based on worst-case assumptions. For example, the calculation of health impacts is based on upper bound estimates of people potentially exposed (maximum number of potentially exposed workers as stated in the questionnaire) and the upper bound of exposure times, as elaborated in the CSR.

As a consequence, human health impacts are highly overestimated and socio-economic impacts are very likely to be underestimated.

6.2. Assessment of health impacts

In accordance with the CSR (3) the risk assessment for workers exposed in this SEA is restricted to inhalation of airborne residues of sodium dichromate (lung cancer). For the general population, inhalation exposure to Cr(VI) and oral exposure to Cr(VI) via the food chain is also taken into account, which leads to an additional risk of intestinal cancer.

Toxicity to reproduction is not addressed in this SEA as the risk is adequately controlled (RCR < 0.01). For details please refer to the CSR (3).

6.2.1 Quantitative health impact assessment of workers

The worst-case assessment of health risks within this SEA utilises the results of a study endorsed by ECHA identifying the reference dose-response relationship for carcinogenicity of Cr(VI) (2)[3]. This paper has been agreed on at the RAC-27 meeting on 04 December 2013. These results on the carcinogenicity dose-response analysis of Cr(VI) containing substances are acknowledged to be the preferred approach of the Committee for Risk Assessment (RAC) and the Committee for Socio-Economic Analysis (SEAC) and therefore have been used as a methodology for the assessment of health risks in this SEA.

Accepting this, the following steps are necessary to complete the health impact assessment according to the ECHA methodology and a worst-case approach:

1. Evaluation of potential work exposure
2. Estimation of additional cancer cases relative to the baseline lifetime risk of developing the disease
3. Assessment of fatality rates (%) with reference to available empirical data
4. Monetary valuation of fatal and non-fatal cancer risks based on the new Willingness to Pay (WTP) study published by ECHA in 2015 (9)

These four consecutive steps are explained in detail in the following.

Data gathering on potential work exposure

For the assessment of potential worker exposure, the maximum number of potentially exposed workers taken from the questionnaire and the worst-case exposure values from the CSR (3) are taken into account. In this course, specific WCSs are taken into account. For further information regarding exposure values, please consider the CSR (3).

Estimation of additional cancer cases in relation to baseline

The dose-response relationship for Cr(VI) with regard to lung cancer has been discussed in recent research published by ECHA (2). These dose-response functions of an excess risk for carcinogenic effects have been used as the basis for this assessment.

For the calculation of health impacts related to lung cancer, **Excess Lifetime Risk** (ELR) is defined as the additional or extra risk of developing cancer due to exposure to a toxic substance incurred over the lifetime of an individual. Note that developing cancer may occur during working life or after retirement.

Linear exposure-risk relationship for lung cancer as estimated by ECHA (2):

$$Unit\ occupational\ excess\ lifetime\ risk = 4\text{E-03}\ per\ \mu g\ Cr(VI)/m^3$$

[3] By reference to this, the applicant neither agrees nor disagrees with this dose-response relationship. However, the applicants acknowledge that the dose-response relationship is likely to be conservative and protective of human health, particularly considering the extrapolated linear relationship at low dose exposure concentrations.

The dose-response relationship agreed upon by RAC refers to a working lifetime exposure with continuous working-daily exposure. As an average over different countries and economic sectors, full-time employee contracts (8 hours per day) and a working lifetime of 40 years are taken as a basis (2). Note that 8 working hours per day or 40 working hours per week, as well as 40 years per working life are explicit parameters used for the Full-Time working Equivalent (FTE) underlying the exposure-response functions (2), p. 5, whereas 260 working days per year are implicitly given through the dose-response curve.

Adaptation factors for time frame of exposure

In order to apply this exposure-risk relationship to the case of authorisation, it has to be adapted according to the time frames used in this AfA.

Therefore, the following factors are used to adapt the exposure-risk relationship to the respective situation of this AfA:

- Factor for adaptation to the respective review period (years of authorisation granted up to the next revision envisaged)

$$\frac{envisaged\ review\ period\ [years]}{40\ years}$$

- Factor for adaptation to the actual working days per year[4]

$$\frac{working\ days\ per\ year}{260\ days}$$

Due to the fact that exposure values derived in the CSR are 8 hour Time Weighted Average (TWA) concentrations, a correction for the actual exposure time per day is not needed.

Methodology for the estimation of additional lung cancer cases

For an individual person, the excess lifetime lung cancer mortality risk derived in the ECHA paper (2) indicates the differential in probability to die of lung cancer during the future life, i.e. the increase in probability compared to the baseline risk for an individual to die from this disease.

As described above and in line with ECHA, ELR of mortality associated with lung cancer = 4E-03 per µg Cr(VI) /m^3 x concentration [µg Cr(VI) /m^3] (due to an exposure over the whole working lifetime of 40 years, which is higher than the relevant time frame for the intended authorisation).

Excess risk used in this equation is defined as:

$$P_{excess} = P(x) - P(0)$$

with

[4] 260 days per year are not explicitly stated in the RAC paper (RAC/27/2013/06 Rev.1), but are implicitly assumed by RAC. This can be shown by comparing the dose-response relationships for workers and the general population.

$P_{excess}(x) = Excess\ risk\ at\ exposure\ x$

$P(x) = lifetime\ risk\ of\ persons\ exposed\ for\ dying\ from\ lung\ cancer$

$P(0) = Background\ risk\ (lifetime\ risk\ of\ a\ non-exposed\ comparison\ group)$

It has to be emphasised that $P_{excess}(x)$ is an additional risk, the unit is the expected number of additional lung cancer deaths of a population exposed by a concentration x in the sum (2).

In the source of ECHA (2), based on the research of the ETeSS consortium (10), and in underlying studies, excess risk is used in absolute terms, not percentage points. The excess risk $P_{excess}(x)$ is linear, i.e. proportional both to individual exposure and to persons exposed. Therefore, exposures of different persons can be added.

Consequently, the aggregated excess risk is the expected value of additional lung cancer deaths due to an exposure.

The calculation of the excess risk (i.e. additional lung cancer deaths) over all employees exposed is calculated per WCS by multiplying the individual excess risk times the respective number of workers exposed. Then, the excess risk of all WCS are summed up. Thus, the estimated amount of additional lung cancer deaths is the expected value due to a continued use of Cr(VI) for the respective time frame allowed by an authorisation up to the next revision.

According to the ECHA document (2), the term used is "*excess lifetime lung cancer mortality risk*". This is also consistent with the results of ETeSS (2013) (10) where the respective table of a preliminary report is titled "*[u]nit occupational excess lifetime risks of lung cancer death determined by different authorities or publications*". This signifies that the dose-response function developed refers only to additional lung cancers ending fatal. In this study, only data on deaths caused by lung cancer have been taken into account for the estimation of the dose-response relationship. This will be included in step 4 of this methodology (Monetary valuation of fatal and non-fatal cancer risks).

Estimation of average fatality rates in %, based on empirical data from EU-27

The individual development of cancer diseases may be fatal or non-fatal. Non-fatal cancer is defined as cancer not causing a premature death, i.e. life expectancy is not reduced due to the cancer disease, whereas fatal cancer is defined as cancer leading to premature death. This distinction is important when applying the ECHA guidance on SEA in order to use consistent categories of monetary values.

For the determination of fatality rates for lung cancer, demographic data on age-specific cancer incidences and mortality rates have been taken into account; these are mainly:

- age profile of a population
- gender profile of a population
- relationship of risk of developing the disease and risk of dying from the disease

For lung cancer, data of the International Agency for Research on Cancer (IARC) (11) for the EU-27, as well as data for the EU Member States, showing the age and gender profile of cancer risks in more detail have been analysed and compared to selected other EU Member States with similar data collection sets (12).

Although the incidence risk and the mortality risk themselves are higher for men than for women, the relationship between incidence and mortality risk (i.e. the fatality rate) shows, apart from random fluctuations, there exist no major differences between males and females.

It has to be emphasised that any structural differences in the baseline risks (e.g. between men and women, between different EU Member States or between different age groups) do not influence the estimation of incremental cancer risks due to exposure to Cr(VI). Therefore, neither the share of male and female workers exposed at work nor the exact age of workers influence the outcome of the estimations.

The fatality rate is an important parameter for a monetary-based valuation of cancer risks. The reference dose-response relationship estimates additional fatal cancer risks only. A full health impact assessment will also consider lung cancer cases that do not result in fatality. Average mortality rates for lung cancer in the EU-27 are 82.8% for both sexes (11). This value will be used for further analyses in this SEA.[5]

Monetary valuation of fatal and non-fatal cancer risks

In order to evaluate the additional cancer cases in monetary terms, monetary values as suggested by the latest study of the Charles University Prague on behalf of ECHA (9) are used.

In the study of Alberini and Ščasný (9), a **WTP** to avoid a statistical case of a cancer [= Value of a statistical case of a cancer (VSCC)] – no matter whether ending non-fatal or fatal – of **EUR 396 000 (2014)** and a Value of a Statistical Life (VSL) for cancer of **EUR 5 000 000 (2014)** are given and recommended to be used for the EU-28. These rounded values are based on an empirical WTP study from the year 2014 using a discrete choice experiment, explicitly addressing cancer risks and 5-year cancer survival probabilities. However, different cancer types such as lung cancer, leukaemia or renal cancers have not been specified in the design. Therefore, these values refer to the whole spectrum of cancers.

We understand from the questionnaire design and the description of the econometric approach used in this study that for each cancer ending fatal, the VSL value for mortality and the VSCC of one cancer case (i.e. the case of one cancer incidence), have to be added. This is because both characteristics

- Chance of getting cancer within the next 5 years, and
- Chance of survival at 5 years from the diagnosis (if you get cancer)

are varied as variables separately from each other in the choice experiment.

[5] In these figures of EU-27, Croatia is not yet included. Respective IARC data for Croatia (with a relatively low population) show an even higher mortality rate of 91.3% for both sexes in the year 2012, but due to the use of relative rates for calculation they cannot directly be aggregated to EU-28. Therefore, the EU-27 parameter is used.

Each cancer ending non-fatal, however, should be evaluated in monetary terms with the VSCC only. Consistently, this methodological approach is also used in the analysis of health impacts in Section 7.1.

Since values are based on the year 2014, they are adjusted to the respective year of the sunset date [the base year for the calculation of Net Present Values (NPV) of costs and benefits] by using Gross Domestic Product (GDP) deflator indexes. This will be explained in the following.

Implementation of a price adjuster

In this SEA, costs and benefits are made comparable by basing them to the year of the sunset date (the sunset date is used as the reference year for all cost estimations of the SEA). Therefore, health risks as well as additional costs relating to the continued use of sodium dichromate in case of the authorisation are based to the year of the sunset date.

To adjust the WTP values to the base year, these values are multiplied by a price adjuster, which is the appropriate price index of the reference year divided by the appropriate price index of the year 2010. When using as appropriate price index the GDP deflator of the EU-28 issued by the statistical office of the European Union (EUROSTAT), complete data could be gathered up to the year 2014. The quarterly deflator is calculated from seasonally adjusted GDP values and rescaled so that 2010 equals 100. For 2014, which is the last year with complete data sets, the deflators of the four quarters range from 105.3 (first quarter) to 106.6 (fourth quarter), with an arithmetic mean of 106.0 for the four quarters.[6] A price index development from 100.0 (in 2010 as the starting point where the index is based on) up to 106.0 in 2014 is equivalent to an **average annual growth factor of 1.015** (geometric mean over 4 years from 2010 to 2014). We assume that in the average the calculated rate of price increase will continue in future from 2014 up to the reference year; therefore, the factor of **1.015 per year** is applied to extrapolate the price index development into the future, i.e. between 2014 and the reference year. Adjusting the WTP values by the GDP deflator from 2014 to the year for which the sunset date is scheduled (i.e. it is implicitly assumed that WTP increases by the same rate as the GDP in average) leads to the respective values for cancer cases. The share of non-fatal cancers has to be added to the estimated number of fatal cancers (see **Table 3**).

Following the recommendations of Alberini and Ščasný (9), it was decided to use the monetary values that are shown in Table 3 for the evaluation of cancer cases.

[6] Source: http://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language=en&pcode=teina110 [Cited: 24 August 2015]. Note that earlier versions of this EUROSTAT source still used an index based on the year 2000 = 100, which was the basis for the calculations in previous SEA documents.

Table 3: Monetary values for fatal and non-fatal lung cancer risks, based on Alberini and Ščasný (9)

	Value of a Statistical Case for a Cancer (VSCC)	**Value of Statistical Life (VSL) for cancer**	**Value for a fatal cancer case: VSL + VSCC**
2014 WTP value based on Alberini and Ščasný – starting value	EUR 396 000	EUR 5 000 000	EUR 5 396 000
Adjusting the 2014 values to the sunset date (2017)	$1.015^{\text{sunset year – 2014}}$	$1.015^{\text{sunset year – 2014}}$	$1.015^{\text{sunset year – 2014}}$
→ 2017 WTP value	EUR 414 089	EUR 5 228 392	**EUR 5 642 481**

As stated before, the average mortality rate for lung cancer in the European Union (EU) is 82.8%. This means that an additional share of 82.8%/17.2% (= 0.208) non-fatal cancers per fatal lung cancer has to be added to the WTP value for a fatal cancer case to get to the total WTP for fatal and non-fatal cancers (see below).

Adding the share of non-fatal lung cancer cases per fatal lung cancer case to get the total WTP	
Probability of lung cancer ending non-fatal (EU-27 average)	17.2%
→ Additional occurrence of non-fatal lung cancer cases per one fatal lung cancer case	17.2%/82.8% (see above) = **0.208** non-fatal lung cancer cases per fatal lung cancer case
→ 2017 WTP value for an additional share of non-fatal lung cancers per fatal lung cancer case (0.208)	**EUR 86 130** (0.208 × EUR 414 089)
→ 2017 Total WTP for one statistical fatal lung cancer case incl. 0.208 non-fatal lung cancer cases per fatal lung cancer case	**EUR 5 728 611** (= EUR 5 642 481 + EUR 86 130)

In order to monetise the excess risk (i.e. additional fatal lung cancers) relating to the authorisation of the continued use of sodium dichromate, first the excess risk is calculated according to the following equation:

Individual ELR per WCS

$$ELR = \frac{review\ period\ [years]}{40\ years} \times \frac{working\ days\ per\ year}{260\ days} \times \text{ 4E-03 per } \frac{\text{µg Cr(VI)}}{\text{m}^3} \times \text{ concentration } \left[\frac{\text{µg Cr(VI)}}{\text{m}^3}\right]$$

where

$$\text{concentration } \left[\frac{\text{µg Cr(VI)}}{\text{m}^3}\right]$$

represents the Cr(VI) concentration taken from the ES in the CSR.

Total ELR over all WCSs and workers

The calculation of the excess risk (i.e. additional fatal lung cancers) over all employees potentially exposed is calculated per WCS by multiplying the individual excess risk times the respective number of workers potentially exposed. Then, the excess risk of all WCS are summed up. Thus, the estimated amount of additional fatal lung cancers is the expected value due to a continued use of Cr(VI) for the respective time frame allowed by an authorisation up to the next revision.

$$\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} (\boldsymbol{ELR_i} \times \boldsymbol{number\ of\ workers_i})$$

i = WCS

Monetisation of the total ELR

In the next step, the monetised value for additional lung cancer cases (fatal and non-fatal) is calculated by multiplication with the WTP value adjusted to the year of the sunset date. Following this methodology, the actual assessment of health impacts related to the authorisation of the continued use of sodium dichromate is conducted in Section 7.1.

6.2.2 Quantitative health impact assessment of the general population

Relevant exposure concentrations

According to ECHA guidance on information requirements and chemical safety assessment Chapter R.16: Environmental exposure estimation, version 2.1, October 2012 (ECHA guidance R.16) (13), potential exposure via the environment should be assessed on two spatial scales: locally in the vicinity of point sources of release to the environment, and regionally for a larger area which includes the point source or all point sources in that area. Releases at the continental scale are not used as endpoints for exposure. The end results of the exposure estimation are Predicted Environmental Concentrations (PECs) in the environmental compartments for both local and regional scale which have been calculated in the ES.

The predicted regional environmental concentration (= MvE regional[7]) derived in the CSR has been assumed to represent the average exposure concentration for the general population. The predicted local environmental concentration (= MvE local), based on modelled data, is used to calculate potential risks for on-site workers not directly exposed as well as the direct neighbourhood.

Number of potentially exposed people

MvE regional

For calculation of the health impacts for the **general population** resulting from potential exposure of Man via Environment (MvE), the total number of people living in an area 200 km x 200 km around the sites that will use sodium dichromate are considered in terms of potential exposure to MvE regional. As a default recommended as the basis of the local exposure assessment in the ECHA guidance R.16 (13), a value of **20 000 000 people per concerned site** is considered as an absolute worst-case in terms of potentially exposed people for MvE regional. The total number of people potentially exposed on a regional scale is then calculated as 20 000 000 multiplied by the number of sites using Cr(VI).

MvE local

The local exposure assessment with MvE local considers workers that do not work with Cr(VI), but work in the vicinity (potentially indirectly exposed workers) as well as people living in the direct neighbourhood of the sites. As a default, the total number of people potentially exposed on a local scale is calculated as 10 000. This number of people is recommended as the basis of the local exposure assessment in the ECHA guidance R.16 (13). Again, the total number of people exposed on a local scale is then calculated as 10 000 multiplied by the number of sites using Cr(VI).

Since there is no basis for a reliable distinction between the number of potentially indirectly exposed workers and people living in the neighbourhood, the dose-response curve for the general population is taken as a basis following the worst-case approach, i.e. workers would be exposed for less time, e.g. 8 hours per day for 260 days, than the general population (24 hours per day for 365 days of exposure). **Table 4** summarises the most important input parameters in case of single sites.

[7] The calculated MvE regional represents the average concentration in an area of 200 km x 200 km around the point sources.

Table 4: Overview of the most important input parameters for calculation of health impacts for MvE

Group of potentially exposed people		Number of potentially exposed people	Exposure concentration to be used from the ES	Dose-response curve for
Indirectly exposed	Potentially indirectly exposed workers and direct neighbourhood	10 000	MvE local	general population
Indirectly exposed	General population in an area of 200 km x 200 km around the site	20 000 000	MvE regional	general population

Adaption factor

The dose-response curves for the general population considers 365 days of exposure and 70 years of life-time. Accordingly, it is necessary to adjust the exposure duration to the foreseen review period of 20 years by the factor 20/70.

Monetisation of health impacts "Man via Environment (MvE)"

In addition to inhalation exposure to Cr(VI) via the environment, for the general population oral exposure to Cr(VI) via the food chain is also taken into respect, which leads to an additional risk of intestinal cancer. Dose-response relationships, but also fatality rates and therefore monetary valuation of cancer cases are different for intestinal cancer than for lung cancer.

The dose-response relationship for Cr(VI) with regard to lung and intestinal cancer for the general population has been discussed in recent research published by ECHA (2).

Linear exposure-risk relationship for lung cancer as estimated by ECHA (2):

$$Unit\ excess\ lifetime\ risk = 2.9\text{E-}02\ per\ \mu g\ Cr(VI)/m^3$$

Linear exposure-risk relationship for intestinal cancer as estimated by ECHA (2):

$$Unit\ excess\ lifetime\ risk = 8\text{E-}04\ per\ \mu g\ Cr(VI)/kg\ bw/day$$

It has to be emphasised that for intestinal cancer the dose-response relationship refers to the incidence and not to fatality of cancer, unlike for lung cancer. According to the ECHA document (2), the term used is "*excess lifetime intestinal cancer risk*". This signifies that the dose-response function developed refers to additional intestinal cancers ending either fatal or non-fatal. In this study, data on cancer incidence, not cancer mortality have been taken into account for the estimation of the dose-response relationship. This will be included in step 4 of this methodology (Monetary valuation of fatal and non-fatal cancer risks).

Estimation of average fatality rates in %, based on empirical data from EU-27

As explained in Section 6.2.1 the individual development of cancer diseases may be fatal or non-fatal. The fatality rate is an important parameter for a monetary-based valuation of cancer risks.

As stated above the reference dose-response relationship for lung cancer estimates the fatal cancer risks, whereas the reference dose-response relationship for intestinal cancer estimates both fatal and non-fatal cancer risks.

According to IARC (11) the average mortality rates for lung and intestinal cancer in the EU-27 are 82.8% and 36.3%, respectively, for both sexes (11), i.e. intestinal cancer has a more favourable survival prognosis than lung cancer. This value will be used for further analyses in this SEA.[8]

Monetary valuation of fatal and non-fatal cancer risks

Analogous to the approach in Section 6.2.1 the additional cancer cases are evaluated in monetary terms, monetary values as suggested by the latest study of the Charles University Prague on behalf of ECHA (9).

As stated before, the average mortality rate for lung cancer and intestinal in the European Union (EU) are 82.8% and 36.3%, respectively.

This means that an additional share of 82.8%/17.2% (= 0.208) non-fatal lung cancers per fatal lung cancer has to be added to the WTP value for a fatal cancer case to get to the total WTP for fatal and non-fatal lung cancers (see **Table 3**). This also means that 63.7% of additional intestinal cancers do not lead to a reduction of life expectancy, and only for the percentage of 36.3% the VSL has to be added (see **Table 5**).

[8] In these figures of EU-27, Croatia is not yet included. Due to the use of relative rates for calculation they cannot directly be aggregated to EU-28.Therefore, the EU-27 parameter is used.

Table 5: Monetary values for fatal and non-fatal intestinal cancer risks, based on Alberini and Ščasný (9)

Adding the share of non-fatal lung cancer cases per fatal lung cancer case to get the total WTP	
Probability of intestinal cancer ending fatal (EU-27 average)	36.3%
→ 2017 WTP value for fatal intestinal cancer cases	**EUR 2 048 220** [0.363 × (EUR 5 228 392 + EUR 414 089)]
→ 2017 Total WTP for one statistical fatal non-fatal/fatal intestinal cancer case	**EUR 2 311 995** (=EUR 2 048 220 + 0.637 × EUR 414 089)

MvE local

Individual ELR lung cancer (local):

$$ELR = \frac{review\ period\ [years]}{70\ years} \times 2.9\text{E-}02 \text{ per } \frac{\mu\text{g Cr(VI)}}{\text{m}^3} \times \text{ MvE local inhalation}$$

Individual ELR intestinal cancer (local):

$$ELR = \frac{review\ period\ [years]}{70\ years} \times 8.0\text{E-}04 \text{ per } \frac{\mu\text{g Cr(VI)}}{\text{kg bw/day}} \times \text{ MvE local oral}$$

where MvE local represents the predicted local environmental Cr(VI) concentration taken from the ES in the CSR.

Total ELR

For the calculation of the total ELR related to MvE local, the total number of potentially indirectly exposed people is assessed taking into account the foreseen population of 10 000 as described in the following formula:

$$Number\ of\ potentially\ exposed\ people\ = number\ of\ sites\ \times\ 10\ 000$$

The calculation of the total excess risks for cancer follows the methodology described in Section 6.2.1 according to the following equations:

ELR lung cancer (local):

$$ELR = \frac{review\ period\ [years]}{70\ years} \times 2.9\text{E-}02 \text{ per } \frac{\mu\text{g Cr(VI)}}{\text{m}^3} \times \text{ MvE local inhalation} \times \text{number of people potentially exposed}$$

ELR intestinal cancer (local):

$$ELR = \frac{review\ period\ [years]}{70\ years} \times 8.0\text{E-}04 \text{ per } \frac{\mu\text{g Cr(VI)}}{\text{kg bw/day}} \times \text{ MvE local oral} \times \text{number of people potentially exposed}$$

Monetisation of total ELR

In the next step, the monetised values for additional cancer cases are calculated by multiplication with the total WTP value for fatal and non-fatal cancers adjusted to the year of the sunset date (see **Table 3** and **Table 5**).

<u>MvE regional</u>

The calculations for the ELR related to MvE regional are equivalent to the calculations related to MvE local only using the regional predicted environmental Cr(VI) concentration (MvE regional) from the ES in the CSR and a different number of potentially exposed people per site (20 000 000) as described above.

Worst-case approach of the quantitative assessment

The overall calculation approach entails an overestimation of health impacts for the following reasons:

- The assumption of a local population of 10 000 per site assumes each site will be located independently and next to a village or town. In general, such sites are likely to be located in areas designated for industrial use, often remote from residential areas. The overall potentially exposed population is therefore likely to be substantially over-estimated.
- On-site workers usually live in the direct neighbourhood or in the surrounding area (200 km x 200 km). Therefore, a double counting appears when calculating health impacts for on-site workers and the general population.
- The risk assessment for workers represents an absolute worst case and is expected to occur at no point in time in reality. This will be further explained in Section 7.1.
- Calculating the excess of risk evolving cancer on basis of the dose-response curve published by ECHA (2) assumes a linear relationship between dose and response, even at low doses (below 0.1 µg/m3). This is a conservative assumption, likely to result in overestimation of the cancer risk.

6.3. Assessment of economic impacts

The economic impacts considered in this SEA are calculated using the NPV of the added value foregone in the NUS.

The NPV is a common methodology applied in economics. It is calculated according to the following equation:

$$NPV\ (i) = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

where

i is the discount rate

N is the number of years for which the NPV is to be calculated (review period)

R_t is the cash flow / the amount of money in year t (e.g. social impacts)

An inflation rate of 1.5%[9] (geometrical mean of annual price increase rate from 2010-2014) was employed to inflate the 2013 values to the base year (2017). To discount the values from 2018-2037 to 2017 values (base year) a discount factor of 4%[10] was employed. See Section 7.2 for the actual assessment of economic impacts connected to the two NUSs of LANXESS.

9 This inflation rate is used for the entire impact assessment.

10 4% is the default discount rate as presented in the ECHA guidance on SEA

7. ANALYSIS OF IMPACTS

In the following section, the expected impacts for the two NUSs are described and assessed. Firstly, the human health and environmental impacts related to the two NUSs are assessed (Section 7.1). The subsequent analysis of the socio-economic impacts in Section 7.2 focuses on social and economic impacts at LANXESS and its stakeholders.

The impact assessment is carried out for a period of 20 years, since this is the remaining working lifetime of the equipment which would be replaced in the two NUSs.

7.1. Human health impacts

As stated in Section 6.2 and in accordance with the corresponding CSR the risk assessment for workers exposed is restricted to inhalation of airborne residues of sodium dichromate (lung cancer).

The assessment of human health impacts considers workers potentially exposed at the LANXESS EPDM plants at the Chemelot industrial complex in Geleen (NL), people potentially exposed in the direct neighbourhood (MvE local) and the general population (MvE regional).

Table 6 depicts the exposure values that were used for the monetisation of health impacts (see corresponding CSR).

Table 6: Exposure values used for the monetisation of potential health impacts to workers

WCS	Activity	Exposure estimate (see CSR) [µg Cr(VI)/m³]
1	Use of sodium dichromate as corrosion inhibitor in ammonia absorption deep cooling systems (PROC 1)	2.3E-07
2	Sampling cooling medium (PROC 9)	6.9E-06
3	Laboratory analysis of cooling medium (PROC 15)	1.8E-05
4	Concentration adjustment (addition of sodium dichromate solution to the cooling circuit) (PROC 8b)	5.2E-03
5	Maintenance (emptying, intermediate storage of the cooling medium and re-filling) (PROC 8b)	7.5E-07

Table 7 below shows the monetised health impacts for workers potentially exposed to sodium dichromate through the use of sodium dichromate in the AADC systems at the LANXESS site in Geleen (NL).

Table 7: Summary of monetised health impacts for potentially exposed workers at LANXESS

	Health impacts for workers [EUR]
Total for 20 years	**3.54**

Further details for the calculation of the values are given in ANNEX A.

Potential exposure to the public has been estimated based on conservative assumptions regarding airborne releases from facilities as well as oral uptake and a substantial population consistent with a small town (10 000 people) at the site boundary (MvE local) and the population of the densely populated area of 200 km x 200 km (MvE regional) amounting to 20 000 000 inhabitants (see **Table 8** for input values used for the monetisation of potential health impacts “Man via Environment”).

Table 8: Exposure values for the monetisation of potential health impacts to the general population

	Exposure estimate
MvE local inhalation	9.1E-07 µg Cr(VI)/m^3
MvE regional inhalation	1.5E-15 µg Cr(VI)/m^3
MvE local oral	4.4E-06 µg Cr(VI)/kg bw/day
MvE regional oral	9.1E-08 µg Cr(VI)/kg bw/day

Table 9 below sets out the monetised health impacts for members of the general population potentially exposed to sodium dichromate and potentially indirectly exposed workers as a result of using sodium dichromate in AADC systems. The analysis is based on a review period of 20 years.

Table 9: Summary of monetised health impacts for the potentially exposed general population

	Health impacts for the general population [EUR]
MvE local inhalation	432
MvE regional inhalation	<0.01
MvE local oral	23
MvE regional oral	962
Total for 20 years	**1 417**

It can be concluded that in total a worst case number of approx. 5.0E-04 additional cancer cases can be attributed to the continued use of sodium dichromate at the LANXESS site in Geleen (NL) for the next 20 years. Differently spoken, approx. the two thousandth(1/2 000) part of a cancer case can be attributed to this use within the next 20 years.

Note: This number is based on the vastly overestimated excess risk related to workers and the general population over a time frame of 20 (!) years (see ANNEX A for details).

7.2. Economic impacts

7.2.1 NUS 1 – Replacement (change) of the cooling system

As mentioned before, there are three EPDM production lines (EPT1, EPT2 and EPT3) operated by LANXESS in Geleen (NL) and the implementation of a new cooling system would lead to different impacts on them. For EPT3 the change of the cooling system would not influence production capacity, but for EPT1 and EPT2 it would imply a capacity decrease of about [redacted] on each of the plants. [redacted]

[redacted]

Table 10: Typical reactor feed temperatures and reactor temperatures for EPT1 and EPT2

EPT1 EPT2	Minimum temperature reactor feed (^{o}C)	Typical reactor temperature	Maximum available temperature difference
AADC	[redacted]	[redacted]	[redacted]
VCC	[redacted]	[redacted]	[redacted]

[redacted][11].

Despite of the fact that LANXESS would have savings with reduction of the variable production costs due to lower energy consumption, the company would have to bear the investment costs and the reduction in the production capacity. Besides that, LANXESS would also face losses due to the downtime during the implementation of the new technology. **Figure 5** illustrates the economic impacts that are considered in this NUS.

[11] For further technical details please refer to the AoA (4)

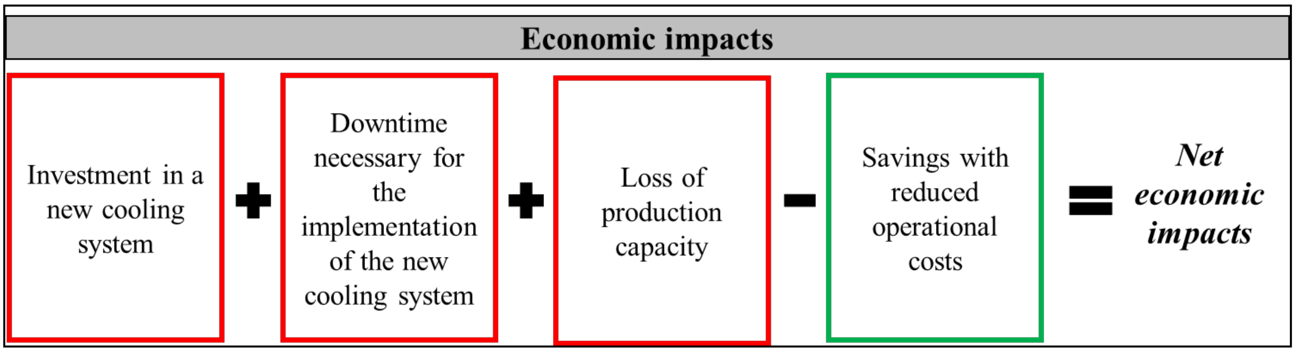


Figure 5: Net economic impacts considered in the NUS

7.2.1.1 Investment costs

In the NUS, the implementation of the VCC system in each of the three production plants will require different amounts of investments. The first two production plants (EPT1 and EPT2) are smaller and the purchase of the new cooling systems will be approximately EUR [redacted] in total. The third production line EPT3 is bigger, has a higher capacity and the investment in the new cooling system for this third plant is estimated to cost approximately EUR [redacted]. Apart from the higher production capacity of EPT3, the reason for the considerable difference in investment costs between EPT1 and EPT2 and EPT3 is the following: [redacted]

The amounts mentioned above include the costs for the equipment, engineering/construction and demolition of the old installation. The estimation of the amounts required for investment was made by taking a recent similar investment made by LANXESS in China as a basis and considering adjustments as follows below:

- In that occasion, the installation of a vapour compression system was budgeted with EUR [redacted][12]. This amount includes only the equipment costs and to that, it is still necessary to add the costs of installation, demolition and connection to the distributed control system of the facility.
- Factor for engineering: installation includes uncertainties (no project scope is available at this moment): equipment cost times a factor of 3;
- Scale-down factor related to required cooling power: [redacted][13].

LANXESS expects that the current cooling system (using ammonia absorption technology), could last for at least 20 years more with very few routine maintenance efforts. For this reason, the purchase of a new cooling system would bring forward an investment that otherwise would only

[12] See ANNEX B for details

[13] The value [redacted] is used as typical value for plants and process units.

happen in **20 years**. The new cooling system is expected to last for 20 years after and therefore, the calculation of the annual cost of the this investment was done considering this period as the total lifetime, 20 years of earlier investment and EUR [redacted] as the total amount required to purchase the new equipment (EUR [redacted]), see **Figure 6**.

[redacted]

Figure 6: Calculation of the NPV of the investment in the new cooling system

As it can be seen, the EUR [redacted] investment annualised in **20 years** results in annual payments of **EUR [redacted].** The NPV of those annual payments calculated for **20 years** represents the impact incurred by the application if the cooling equipment has to be changed before the sunset date due to a non-granted authorisation. Since the lifetime of the new equipment is exactly the same as the remaining life of the old equipment, the NPV was calculated considering all 20 annual payments, therefore resulting in an NPV that amounts exactly to the total amount of the investment: **EUR [redacted].**

7.2.1.2 Downtime

Another factor that adds to the economic impacts in case of non-authorisation is the production downtime caused by the implementation of the new cooling system. LANXESS expects that the implementation process of the new technology would take approximately 2 years. This time refers to the whole implementation and its different steps:

- engineering of new cooling system
- planning of plant shut down
- construction of the new cooling unit
- integration of the new cooling unit in the existing plant systems

Meanwhile the new cooling system is implemented, production lines will have to be shut down resulting in opportunity cost for the company. The total duration while the production would have to be stopped is estimated to take [redacted][14]. The plants are planned[15] to be running at full capacity and continuously (24 hours/day, 7 days/week), not being able to replace the cooling system without a production stop. The calculation of the opportunity cost during this period was done using a metric suggested by members of SEAC in previous AfAs: *the added value foregone*. In order to calculate the added value foregone, the costs of inputs (except capital and labour) are subtracted from the turnover (net sales).

$$added\ value\ foregone = turnover\ (net\ sales) - costs\ of\ inputs\ (except\ capital\ \&\ labour)$$

For the calculation of the added value foregone it is necessary to consider the expected development of the company's turnover in the upcoming years. Even though the EPDM market is expected to grow (see Section 3.5), for the assessment of economic impacts it will be assumed that the turnover would be constant in real terms during the assessment period. This is to avoid overestimation of economic impacts.

Added value foregone

In 2013, the turnover of the LANXESS facility in Geleen (NL) which is related to EPDM production reached EUR [redacted] while the production costs (excluding labour and capital costs) amounted to EUR [redacted]. Therefore, the annual amount of added value reaches EUR [redacted]. Taking into account that, in 2013, [redacted] tonnes of EPDM were produced, the added value per tonne amounts to approximately EUR [redacted]. Considering that in real terms this amount would keep at least constant and that the production would have to be shut down for a period of [redacted], [redacted], the impact of the downtime due to the implementation of the alternative is calculated below in **Table 11**.

[14] Also this estimation is the absolute minimum downtime and therefore taken for the assessment in this SEA. However, more realistic estimates would be in the range of [redacted].

[15] [redacted]

Table 11: Added value foregone with downtime in 2013 price levels

Turnover related to EPDM production in Geleen (NL) (2013) [EUR]	Production costs (excl. labour and capital) in 2013 [EUR]	Added value (year) [EUR]	Volume produced a year (tonnes)	Added value per ton [EUR]	Number of working weeks
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calculation of the added value foregone in [redacted] considering full capacity and constant added value per ton:			[redacted]	[redacted]	[redacted]
Value added foregone with a [redacted] shutdown/downtime [EUR] ([redacted])					[redacted]

Since all amounts will be compared in 2017 values (base year), the added value foregone calculated above has been inflated from 2013 to 2017 using the same GDP deflator as used for health impacts calculation, see **Table 12**.

Table 12: Adjusted added value foregone in 2017 price levels

Value added foregone in 2013 price level) [EUR]	Number of years (2013-2017)	Inflation factor/year - based on the GDP deflator	Value added foregone in 2017 price level) [EUR]
[redacted]	4	1.015	[redacted]

As it can be seen, the added value foregone due to downtime considered and using the level of prices from 2017 amounts to approximately **EUR** [redacted].

7.2.1.3 Loss of production capacity

As explained in Section 7.2 and the AoA, the VCC system would have the disadvantage of decreasing the capacity of EPT1 and EPT2 by [redacted] each (4).

The capacity of each of those two production plants is [redacted] tonnes and therefore, a reduction of [redacted] of a combined production capacity of [redacted] tonnes ([redacted]) would result in a loss of [redacted] tonnes of output. In terms of added value foregone, the same value per tonne as calculated on **Table 11** was used for calculation of the added value foregone per year, see below in the **Table 13**.

Table 13: Calculation of annual value foregone due to capacity reduction in 2013 price levels

Calculation of the loss of production capacity	Volume (tonnes)	Value added forgone (turnover minus all production costs excl. labour and capital) = ([redacted] x EUR [redacted]) [EUR]
Capacity reduction of [redacted] of EPT1 and EPT2	[redacted]	[redacted]

Since the added value foregone calculated refers to values from 2013, the amount has to be adjusted to 2017 using the same inflation factor as mentioned in **Table 12** (1.015 a year) for 4 years (2013 to 2017), see **Table 14**.

Table 14: Adjusted added value foregone due to capacity reduction in 2017 price levels

Value added foregone in 2013 price level) [EUR]	Number of years (2013-2017)	Inflation factor/year - based on the GDP deflator	Value added foregone in 2017 price level) [EUR]
[redacted]	4	1.015	[redacted]

Considering the whole assessment period, the NPV of the annual added value foregone of approx. **EUR** [redacted] for 20 years (assessment period) would represent the economic impact of the reduced production capacity, see calculation below on the **Figure 7**.

[redacted]

Figure 7: NPV of 20 years of added value foregone due to capacity reduction

Considering the whole assessment period of 20 years, the added value foregone due to capacity reduction reaches approx. **EUR** [redacted] in 2017.

7.2.1.4 Savings with reduced operational costs

Apart from the "negative" economic impacts that would be induced by the implementation of the VCC system (see sections above), the new cooling system would also bring benefits in terms of reduction in operational costs. To get to the net economic impact of this NUS, those need to be subtracted from the negative impacts which arise from the NUS assessed in Sections 7.2.1.1 to 7.2.1.3.

[redacted]

LANXESS has analysed its future cooling costs in the case the new cooling system would be installed. As it can be seen from the following tables, the cooling costs for absorption cooling amount to approx. EUR [redacted] yearly. The amount of steam needed per tonne of product, the yearly production volume and the steam price, divided into variable and fixed amount is given below.

Table 15: Cooling costs – Absorption cooling

[redacted]

After the switch to the VCC, the driving energy is replaced by electricity. The properties of the new system can be seen in **Table 16**.

Note the reduced production capacity for EPT1 and EPT2 due to the change of the cooling system.

Table 16: Cooling costs – Vapour compression cooling

[redacted]

Table 17 shows the difference in cooling costs which is derived from the tables above. [redacted] Overall, the savings will be approx. **EUR** [redacted] per year (EUR [redacted]) in the first 5 years and approx. **EUR** [redacted] (EUR [redacted]) per year in the following years.

Table 17: Differences in cooling costs

[redacted]

Considering the whole period of assessment (20 years), the NPV of the annual savings for this period is an indicator of the economic benefit of switching to the alternative due to savings. The NPV as calculated below on **Figure 8** totalises to approximately **EUR** [redacted].

[redacted]

Figure 8: Savings with reduced operational costs

7.2.1.5 Total impacts

Summing up all economic impacts that would arise in this NUS (new investment, loss of capacity, downtime) and deducting the amount that would be saved due to reduction in the production costs, the net economic impacts of the NUS can be summarised as follows in **Table 18**.

Table 18: Net Economic Impacts – replacement (change) of the cooling system

Type of impact	[EUR]
Investment in a new cooling system	[redacted]
Value added foregone due to downtime	[redacted]
Value added foregone due to capacity reduction	[redacted]
Savings due to reduction on the production costs	[redacted]
Net economic impacts	[redacted]

7.2.2 NUS 2 - Replacement of corrosion prone parts

As mentioned in Section 4.2, the replacement of parts of the current AADC system that are currently made of carbon steel for parts made of stainless steel represents an uncertain but in principle possible NUS. Regardless of the uncertainties connected to this NUS, it is assessed here. Economic impacts to be considered consist of the investment costs for the stainless steel parts and the expenses for deconstruction of the "old" parts and the installation of the new parts (Section 7.2.2.1) as well as the expected downtime of production for the replacement of the parts (Section 7.2.2.2). Following the worst-case approach, only the pure investment costs for the stainless steel parts are considered in the following analysis. In addition, the lowest estimate for the expected downtime for replacement of the parts was taken as an input parameter for the estimation of economic impacts connected to the downtime.

7.2.2.1 Investment costs

As elaborated already in Section 4.2 of this report, the investment costs for the stainless steel parts would be EUR [redacted] for one cooling system (equipment costs only). This does not include labour costs for deconstruction and construction of the new system. Similar to the cost estimate for a replacement of the entire cooling system (see Section 7.2.1.1), an engineering factor of 3, which is commonly used for industrial projects, is needed for a realistic estimate of the total cost to replace the corrosion prone parts of the system.

LANXESS expects that the current cooling system (using ammonia absorption), could last for 20 years more with very few routine maintenance efforts. For this reason, the purchase of new equipment would bring forward an investment that otherwise would only happen in **20 years**. Since there is absolutely no experience available with stainless steel parts in AADC systems in the industrial scale, the lifetime of this equipment cannot be estimated, but is expected to be considerably shorter than the current one. However, to keep the **worst case approach**, **20 years of functional lifetime** of the stainless steel parts are taken as input for the following calculations. In addition, it is expected that due to the lack of experience, the costs for routine checks and maintenance will be considerably higher than with the current system, but also these costs are not factored in here. Consequently, the following estimation represents a conservative lower bound of expected economic impacts in this NUS.

The new equipment is expected to last for 20 years. Therefore, the calculation of the NPV of this investment was done considering 20 years of total lifetime, 20 years of earlier investment and EUR [redacted] as the total amount required to purchase the new equipment, dismantle the existing one and install the new equipment ([redacted]).

Since the lifetime of the new equipment is exactly the same as the remaining life of the old equipment (conservative assumption), the NPV was calculated considering all the 20 annual payments, therefore resulting in an NPV that amounts exactly to the **total amount of the investment, EUR** [redacted] (c.f. NUS 1 in Section 7.2.1.1 above).

7.2.2.2 Downtime

Similar to NUS 1 – change to another cooling system – the expected minimum downtime for the replacement of parts by stainless steel parts is [redacted]. Therefore, the economic impact resulting from the downtime in the NUS – replacement of parts – is the same as in the abovementioned scenario 1. The monetised impact in this case is **EUR** [redacted]**.**

7.2.2.3 Total impacts

Table 19: Net Economic Impacts – replacement of corrosion prone parts

Type of impact	[EUR]
Investment in new parts for the cooling system	[redacted]
Value added foregone due to downtime	[redacted]
Net economic impacts	[redacted]

7.3. Social impacts

Neither the investment in a new cooling system for the adoption of the new technology (NUS 1), nor the exchange of parts for the cooling system (NUS 2) is expected to result in any dismissals. Therefore no job losses are expected to happen in the two assessed NUS.

In the long term perspective, there might be further social impacts in case a new cooling system is proven not to be economically sustainable, as it is explained in Section 7.5.

7.4. Wider economic impacts

Considering NUS 1, it is expected that LANXESS would suffer losses in competitiveness due to the reduced production capacity (which would not only have a financial impact in terms of sales but consequently would affect the market share that LANXESS has in the EPDM market).

The forced downtime of production in NUS 1 and NUS 2 could incur wider economic impacts in the sense that other companies could take advantage of the period while the applicant would perform no production by means of acquiring new clients which previously were supplied by LANXESS Besides that, the future growth of LANXESS would also be impacted in terms of a lower market share in a growing market where scale is highly important to cover fixed costs and to produce profitably.

7.5. Further impacts in case of a future shutdown

In case LANXESS suffers stronger competition than previously forecasted (due to the reduced capacity or frequent maintenance downtimes) and starts facing problems regarding the economic feasibility of the operation in Geleen (NL), there is a possibility that the facility would have to be closed and this would lead to much higher impacts than those already mentioned in the previous section.

Among the losses/impacts, perhaps one of the most socially relevant would be the loss of jobs within the Netherlands. As already mentioned, the LANXESS site Geleen (NL) employs almost [redacted] people and pays around EUR [redacted] in salaries annually.

In economic terms, the losses measured as added value foregone can be estimated to be more than six times the value calculated for the NUS "replacement (change) of the cooling system" (given the fact that the use of a new cooling system would mean a reduction of [redacted] in the total production capacity, shutting down the facility is equivalent to losing 100% of the capacity).

Wider economic impacts happening would be much more relevant since they would comprise lower taxes collected by governments in the Netherlands and losses in competitiveness in the European EPDM market (which is highly relevant for the automotive and construction sectors).

8. COMBINED ASSESSMENT OF IMPACTS

To summarise the previous assessment and to estimate the overall costs and benefits of a decision to grant or deny this AfA, a combined assessment of impacts is set out here. A subsequent uncertainty analysis aims to assess the effects of uncertainties on the overall result of the SEA.

8.1. Comparison of impacts

Table 20 summarises the effects of a non-authorisation.

Table 20: Comparison of impacts for the applied for use and the non-use scenario

Type of impact	Applied for use scenario	Non-use scenario
Human health	• Minimal health impacts due to the potential exposure of workers and the general population due to the use of sodium dichromate at the LANXESS site in Geleen (NL).	• No potential exposure of workers and the general population due to the use of sodium dichromate at the LANXESS site in Geleen (NL).
Environmental impacts	• Negligible environmental impacts related to sodium dichromate.	• No environmental impacts related to sodium dichromate in Europe.
Economic impacts	NUS 1 • No investment in cooling systems needed for the next 20 years • Full production capacity • No cost of downtime NUS 2 • No replacement of parts necessary • No cost of downtime • No uncertainties regarding the reliability of the corrosion protection	NUS 1 • Investment in a new cooling system needed in 2017 • Loss of [redacted] of capacity on plants EPT1 and EPT2 • Cost of minimum [redacted] downtime NUS 2 • Replacement of parts of the cooling system necessary • Cost of minimum [redacted] downtime • Uncertainty about reliability, lifetime and required maintenance intervals of the new parts
Wider Economic impacts	• More competition in the EPDM market	• Less competitive EPDM market

Table 21 below summarises the impacts for the applied for use and the NUS in terms of monetised costs and benefits which were calculated in Section 7.

Table 21: Quantitative comparison of impacts for the applied for use and the non-use scenario

Type of impact	NUS 1 [EUR]	NUS 2 [EUR]
potential health benefits associated with a non-authorisation of the continued use of sodium dichromate	**3.54**	**3.54**
potential health benefits "Man via Environment" associated with a non-authorisation of the continued use	**1 417**	**1 417**
Negative economic impacts associated with a non-granted authorisation	[redacted]	[redacted]
Net benefits of a granted authorisation	[redacted]	[redacted]

Summing up, the ratio of health benefits of a non-granted authorisation to the negative economic impacts of a non-granted authorisation is 1 : >10000 for both NUSs (NUS 1: approx. 1 : [redacted], NUS 2: approx. 1 : [redacted]).

8.2. Qualitative assessment of uncertainties

The ECHA guidance on SEA (1) proposes an approach for conducting the uncertainty analysis. This approach provides three levels of assessment that should be applied if it corresponds.

- Qualitative assessment of uncertainties
- Deterministic assessment of uncertainties
- Probabilistic assessment of uncertainties

The ECHA guidance on SEA further states that the level of detail and dedicated resources to the assessment of uncertainties should be in fair proportion to the scope of the SEA. Further assessment of uncertainties is only needed, if assessment of uncertainties are of crucial importance for the overall outcome of the SEA.

Hence, a qualitative assessment of uncertainties has been conducted to summarise and describe potential sources of uncertainty related to the impact categories. Given the ratios of health to economic impacts, a deterministic or probabilistic analysis of uncertainties is not expected to be of crucial importance for the overall outcome. Therefore, these analyses have not been conducted for this SEA. **Table 22** illustrates the systematic identification of uncertainties related to human health impacts.

Table 22: Uncertainties on human health impacts

Identification of uncertainty (assumption)	Classification	Evaluation	Criteria and scaling (contribution to total uncertainty)
Shape of exposure-response function (linear versus non-linear)[16]	Model uncertainty	If non-linear, particularly at low exposure levels: **overestimation**	High
Working days (260 days) given by the dose-response curve	Parameter uncertainty	Not taking into account holidays, bank holidays, illness: **overestimation**	Medium
MvE local includes exposure concentration of MvE regional	Parameter uncertainty	Double counting of health impacts for people already considered in MvE local values: **overestimation**	Low

[16] The study conducted by ETeSS on behalf of ECHA clearly states that: "*[…] the lower the exposure (certainly below 1µg/m^3), the more likely it is that the linear [dose-response] relationship overestimates the cancer risk.*" The study further states that "*the risk estimates for […] exposures lower than 1 µg Cr(VI)/m^3 might well greatly overestimate the real cancer risks. It is also considered that at progressively lower Cr(VI) air concentrations (from about 0.1 µg/m^3 downwards), cancer risks may be negligible.*" (2)

9. CONCLUSIONS

The aim of this SEA is to describe the socio-economic impacts of a non-granted authorisation of continued use of sodium dichromate according to the use description defined in Section 3 and compare them to the residual risks to human health in case of a granted authorisation. Given the aims of the SEA, the analysis purposefully sought to characterise certain impacts but also, where appropriate, to over-value health impacts and to under-value real socio-economic impacts. This approach supports confidence in the findings of the assessment.

The outcomes of this SEA for an **assessment period of 20 years** are briefly summarised in the following. Details of the calculations can be found in Section 7.

Monetised residual risks to human health and the environment of a granted authorisation

- **EUR 1 421** including health impacts to workers and the general population (see Section 7.1)[17]

Socio-economic impacts of a non-granted authorisation:

NUS 1 - Replacement (change) of the cooling system:

- Net economic impacts related to new investments, savings with new technology, loss of production capacity and downtime amounting to approx. **EUR** [redacted] (see Section 7.2.1)

NUS 2 - Replacement of corrosion prone parts:

- Net economic impacts related to new investment and downtime needed to replace parts of the cooling systems amounting to approx. **EUR** [redacted] (see Section 7.2.2)

Referring to the figures stated above, the quantitative assessment clearly supports a conclusion that the benefits of continued use outweigh the risks to human health and the environment (see summary table of the impact assessment in Section 8.1). The CSR indicates exposure to workers and the public is well managed and very limited. Taking into account that health impacts are certainly vastly overestimated, this outcome can be considered as robust.

In the light of recent developments regarding the inclusion of the business division concerned in this AfA in a joint venture announced by the LANXESS Group and Saudi Aramco on 22 September 2015 (LANXESS, 2015), it is important to emphasize that the merger will not have any influence on the situation regarding alternatives nor the impacts described in this SEA.

A review period of 20 years was selected because it coincides with the estimated remaining lifetime of the equipment which will have to be replaced by LANXESS in the two assessed NUSs.

[17] This equals one statistical cancer case in 40 000 (!) years of use of the substance under prevalent use conditions at the LANXESS site in Geleen (NL).

Apart from the outcomes of the quantitative impact assessment conducted in this SEA, it should be noted that a non-authorisation would most probably incur competitive disadvantages for LANXESS in comparison to their non-EEA competitors which might subsequently lead to a non-favourable market position of LANXESS. In the worst-case, this could evolve to a situation, where LANXESS would not be able to compete with its non-EEA competitors and therefore might have to cease production at the site in Geleen (NL). In addition to that, stringent regulations, including the Carcinogens and Mutagens Directive (2004/37/EC), are in place that require implementation of measures to minimize workplace exposure to Cr(VI). Appropriate and efficient controls are in place to protect and comply with the environmental, health and safety regulatory requirements. It is expected that ongoing improvements will be effected as industry continues its commitment to minimise exposure.

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ANNEX A HEALTH IMPACT ASSESSMENT

Number of potentially exposed people

Table 23 provides the relevant number of potentially exposed workers at LANXESS, potentially indirectly exposed workers and the potentially exposed general population which needs to be considered for the exposure route Man via Environment (MvE).

Table 23: Number of people potentially exposed

Industrial workers at LANXESS site in Geleen (NL)	Max. [redacted] [18]
General population (MvE regional)	1 site x 20 000 000 people
Potentially indirectly exposed workers and direct neighbourhood (MvE local)	1 site x 10 000 people

The AfA to continue the use of sodium dichromate as corrosion inhibitor in ammonia absorption deep cooling systems is restricted to one specific industrial use only. Therefore, professional workers are not listed in the table above.

The human health impact assessment in the following sections is based on the methodology suggested by ECHA and described in Section 6.2 of this SEA.

Calculation of health impacts for potentially exposed people

Following the methodology described in Section 6.2, the calculation of the monetised health impacts for the continued use of sodium dichromate at LANXESS production site in the Chemelot industrial complex in Geleen (NL) is given by the following equations. The exposure values derived in the respective CSR are used corrected by the exposure times and the maximum number of potentially exposed people to calculate the total ELR (see **Table 24**).

[18] Includes all personnel that may be present at the site at one time. Note: not all personnel is present on the site during all shifts. Number of potentially directly exposed people per WCS, see **Table 23**

Table 24: Activities (WCSs) and resulting ELRs

WCS	Exposure estimate (see CSR) [µg Cr(VI)/m^3]	days of exposure per year	Factor to adjust to 260 work days[19]	time corrected exposure estimate [µg Cr(VI)/m^3]	ELR	Factor to adjust to review period (20 years/40 years)	ELR adjusted to review period	Max. number of potentially exposed workers	Max. ELR for potentially exposed workers (adjusted to frequency and review period)	Monetised value [EUR]
1	2.3E-07	1095[20]	4.21	9.7E-07	3.9E-09	0.5	1.9E-09	[redacted]	[redacted]	[redacted]
2	6.9E-06	12	0.046	3.2E-07	1.3E-09	0.5	6.5E-10	[redacted]	[redacted]	[redacted]
3	1.8E-05	12	0.046	8.3E-07	3.3E-09	0.5	1.7E-09	[redacted]	[redacted]	[redacted]
4	5.2E-03	6	0.023	1.2E-04	4.8E-07	0.5	2.4E-07	[redacted]	[redacted]	[redacted]
5	7.5E-07	2	0.0077	5.8E-09	2.3E-11	0.5	1.2E-11	[redacted]	[redacted]	[redacted]
										3.54

See **Table 25** for description of the activities carried out in the respective WCS.

Table 25: Activities (WCSs) relevant for potential worker exposure

WCS	Activity
1	Use of sodium dichromate as corrosion inhibitor in ammonia absorption deep cooling systems (PROC 1)
2	Sampling of cooling medium (PROC 9)
3	Laboratory analysis of cooling medium (PROC 15)
4	Concentration adjustment (addition of sodium dichromate solution to the cooling circuit) (PROC 8b)
5	Maintenance (emptying, intermediate storage of the cooling medium and re-filling) (PROC 8b)

[19] Days of exposure per year / 260

[20] Differing from the CSR, as a worst-case scenario for the purpose of the SEA, it is assumed here that all people that may be present at the site at the same time ([redacted]) are exposed 24/7 for 365 days per year in 3 shifts. Therefore, the total number of days with exposure was calculated as 365 days times 3. Please note that this represents a vast overestimation of health impacts.

Based on the value for the total ELR which is calculated according to the following equation and a review period of 20 years (see **Table 24**),

$$ELR = \frac{20\ years}{40\ years} \times 4\text{E-03 per } \frac{\mu\text{g Cr(VI)}}{\text{m}^3} \times \text{concentration } \left[\frac{\mu\text{g Cr(VI)}}{\text{m}^3}\right]$$

the equation for the calculation of the monetised health impacts for workers at the LANXESS site in Geleen (NL) is as follows

$$monetary\ value\ for\ fatal\ and\ non-fatal\ lung\ cancers\ =\ ELR\ \times EUR\ 5\ 728\ 611$$

Table 26 summarises the monetised impacts derived from the equations above derived in accordance with the ECHA guidance on SEA, for workers potentially exposed to sodium dichromate at the LANXESS site in Geleen (NL) when continuing the use of sodium dichromate in AADC systems. The analysis is based on a review period of 20 years. Following the worst-case approach by applying upper bound number of potentially exposed people at the LANXESS site in Geleen (NL).

Table 26: Monetised health impacts for potentially exposed workers at the LANXESS site in Geleen (NL).

Group of potentially exposed people	Monetised value [EUR]
Workers	**3.54**

For information purposes, the maximum frequency corrected ELR that could in theory be reached if only 2 people would conduct all activities described under WCSs 1, 2, 4 and 5 during 20 years would be 4.8E-07. However, for the health impact assessment in the SEA, it was concluded that the assessment as described above is closer to reality albeit representing an overestimation of impacts. Due to the fact that the monetised value of health impacts for workers is negligible compared to the economic impacts, further investigation of the health impacts to workers is not conducted here.

Potentially exposed population “Man via Environment” human health impact assessment

The applied methodology and main underlying assumptions are given in Section 6.2.2. The calculations are provided for MvE local and MvE regional and follow generally the calculations presented for the health impact assessment of potentially exposed workers. It should be noted that the following calculations are based on worst-case assumptions and therefore have to be regarded as overestimated. This fact is given by the very high number of people potentially exposed, which was taken into account following ECHA guidance R.16 (13). Additionally, there is uncertainty about the dose-response curve at very low exposure values. The linear dose-response curve recommended by RAC might be too conservative for this exposure level (see 6.2 for further information).

MvE local

The total number of potentially indirectly exposed people is assessed taking into account the foreseen population of 10 000 people around one industrial site (13).

$$Number\ of\ potentially\ exposed\ people\ (local) = number\ of\ sites\ \times\ 10\ 000 = 1 \times 10\ 000 = \mathbf{10\ 000}$$

With the exposure values for MvE local provided by the CSR and the above calculated number of potentially exposed people the further calculation follows the methodology described in Section 6.2:

The excess risks are calculated according to the following equations:

ELR lung cancer (local):

$$ELR = \frac{review\ period\ [years]}{70\ years} \times 2.9\text{E-02 per } \frac{\mu\text{g Cr(VI)}}{\text{m}^3} \times \text{ MvE local inhalation} \times \text{number of people potentially exposed}$$

$$= \frac{20\ years}{70\ years} \times 2.9\text{E-02 per } \frac{\mu\text{g Cr(VI)}}{\text{m}^3} \times 9.1\text{E-07 } \frac{\mu\text{g Cr(VI)}}{\text{m}^3} \times 10\ 000$$

ELR intestinal cancer (local):

$$ELR = \frac{review\ period\ [years]}{70\ years} \times 8.0\text{E-04 per } \frac{\mu\text{g Cr(VI)}}{\text{kg bw/day}} \times \text{ MvE local oral} \times \text{number of people potentially exposed}$$

$$= \frac{20\ years}{70\ years} \times 8.0\text{E-04 per } \frac{\mu\text{g Cr(VI)}}{\text{kg bw/day}} \times 4.4\text{E-06 } \frac{\mu\text{g Cr(VI)}}{\text{kg bw/day}} \times 10\ 000$$

In a second step, the monetised values for additional cancer cases is again calculated by multiplication of the ELR with the WTP value adjusted to the year of the sunset date:

Monetary value lung cancer:

$$monetary\ value\ for\ fatal\ and\ non-fatal\ lung\ cancers = ELR\ \times EUR\ 5\ 728\ 611$$

Monetary value intestinal cancer:

$$monetary\ value\ for\ fatal\ and\ non-fatal\ intestinal\ cancers = ELR\ \times EUR\ 2\ 311\ 995$$

Table 27 shows the monetary value for health impacts for MvE local.

Table 27: Monetised potential health impacts for MvE local

General population – local	**monetised value [EUR]**
MvE local inhalation	432
MvE local oral	23
Total	**455**

MvE regional inhalation

The total number of potentially indirectly exposed people is assumed with a population of 20 000 000 people around one industrial site.

$$Number\ of\ potentially\ exposed\ people\ (\ regional) = number\ of\ sites\ \times 20\ 000\ 000$$
$$= 1 \times 20\ 000\ 000 = \mathbf{20\ 000\ 000}$$

With the exposure values for MvE regional provided by the CSR and the above calculated number of potentially exposed people the further calculation follows the methodology described in Section 6.2.

The excess risks are calculated according to the following equations:

ELR lung cancer (regional):

$$ELR = \frac{review\ period\ [years]}{70\ years} \times 2.9\text{E-02 per } \frac{\mu\text{g Cr(VI)}}{\text{m}^3} \times \text{ MvE regional inhalation} \times \text{number of people potentially exposed}$$

$$= \frac{20\ years}{70\ years} \times 2.9\text{E-02 per } \frac{\mu\text{g Cr(VI)}}{\text{m}^3} \times 1.0\text{E-15 } \frac{\mu\text{g Cr(VI)}}{\text{m}^3} \times 20\ 000\ 000$$

ELR intestinal cancer (regional):

$$ELR = \frac{review\ period\ [years]}{70\ years} \times 8.0\text{E-04 per } \frac{\mu\text{g Cr(VI)}}{\text{kg bw/day}} \times \text{ MvE regional oral} \times \text{number of people potentially exposed}$$

$$= \frac{20\ years}{70\ years} \times 8.0\text{E-04 per } \frac{\mu\text{g Cr(VI)}}{\text{kg bw/day}} \times 9.1\text{E-08 } \frac{\mu\text{g Cr(VI)}}{\text{kg bw/day}} \times 20\ 000\ 000$$

In a second step, the monetised values for additional cancer cases are calculated by multiplication of the ELR with the WTP value adjusted to the year of the sunset date (see above).

Table 28 shows the monetary value for health impacts for MvE local.

Table 28: Monetised potential health impacts for MvE regional

General population – regional	Monetised value [EUR]
MvE regional inhalation	<0.01
MvE regional oral	962
Total	**962**

Summary

Table 29 provides a summary of total health impacts for workers and the general population related to the use of sodium dichromate at LANXESS facilities.

Table 29: Summary table – monetised potential health impacts

Type of potentially exposed population	[EUR]
Potentially exposed workers	3.54
Potentially indirectly exposed workers and direct neighbourhood (MvE local)	455
General population 200 km x 200 km (MvE regional)	962
Total	**1 421**

It can be concluded that in total a worst case number of approx. 5.0E-04 additional cancer cases can be attributed to the continued use of sodium dichromate at the LANXESS site in Geleen (NL) for the next 20 years. Differently spoken, approx. the two thousandth (1/2 000) part of a cancer case can be attributed to this use within the next 20 years.

This equals one statistical cancer case in 40 000 (!) years of use of the substance under prevalent use conditions at the LANXESS site in Geleen (NL).

Note: This number is based on the vastly overestimated excess risk related to workers and the general population over a time frame of 20 (!) years.

ANNEX B QUOTATION FOR VCC SYSTEM (EXCERT)

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]