A | Bewertung der Methoden zur Berechnung der ökologischen Wirkungskategorien

Tabelle 1 — Bewertung der Methoden zur Berechnung der Wirkungskategorie Climate Change

			Methode				
Quelle	**Prüfindikator**	**Wirkungskategorie**	IPCC midpoint only	EPS2000 endpoint	ReCiPe endpoint	EcoIndica-tor99 endpoint	LIME midpoint
Joint Research Centre (2011, S. 14 ff.)	Scope	Climate Change	1	1	1	3	2
	Relevance	Climate Change	1	2	1	3	1
	Robustness & Certainty	Climate Change	1	4	2	3	2
	Documentation, Transparency & Reproducibility	Climate Change	1	1	1	1	5
	Applicability	Climate Change	2	2	2	2	2
	Overall evaluation of Science-based Criteria	Climate Change	1	3	2	3	3
	Stakeholder Acceptance	Climate Change	1	4	4	4	5
		Summe	8	17	13	19	20

Die Bewertung der Prüfindikatoren folgt den Erkenntnissen des Joint Research Centre (2011). Dabei wurde der Bewertungsskala jeweils ein numerischer Wert zugewiesen. 1: full compliance; 2: compliance in all essential aspects; 3: compliance in some aspects; 4: little compliance; 5: no compliance. Die Prüfkriterien sind: Scope; Relevance, Robustness and Certainty; Documentation, Transparency and Reproducibility; Applicability; Overall Evaluation of Science based Criteria; sowie Stakeholder Acceptance. Demnach erfüllen jene Methoden mit der niedrigsten Gesamtsumme über alle Prüfkriterien die Prüfindikatoren bestmöglich.

Tabelle 2 — Bewertung der Methoden zur Erfassung der Wirkungskategorie Ozone Depletion

Quelle	Prüfindikator	Wirkungskategorie	Methode				
			WMO midpoint	EcoIndicator99 endpoint	EPS2000 endpoint	LIME endpoint	ReCiPe endpoint
Joint Research Centre (2011, S. 14 ff.)	Scope	Ozone Depletion	1	3	2	1	3
	Relevance	Ozone Depletion	1	2	3	1	2
	Robustness & Certainty	Ozone Depletion	1	3	4	2	1
	Documentation, Transparency & Reproducibility	Ozone Depletion	1	1	2	2	1
	Applicability	Ozone Depletion	2	2	2	2	2
	Overall evaluation of Science-based Criteria	Ozone Depletion	1	3	4	2	2
	Stakeholder Acceptance	Ozone Depletion	1	3	2	4	2
		Summe	8	17	19	14	13

Tabelle 3 — Bewertung der Methoden zur Erfassung der Wirkungskategorie Human Toxicity

			Methode							
Quelle	**Prüfindikator**	**Wirkungskategorie**	USEtox midpoint	ReCiPe mid- & endpoint	IMPACT2002+ mid- & endpoint	TRACI midpoint	EDIP 2003 midpoint	CML 2002 midpoint	MEEuP midpoint	EPS 2000 endpoint
Joint Research Centre (2011, S. 25 ff.)	Scope	Human Toxicity	1,5	2	1	2,5	2,5	1,5	5	3
	Relevance	Human Toxicity	2	2	2	3	3	2	4,5	4
	Robustness & Certainty	Human Toxicity	2	2	2	2	3	2	no evaluation	3
	Documentation, Transparency & Reproducibility	Human Toxicity	1	1,5	1,5	1	1	1	no evaluation	2
	Applicability	Human Toxicity	1	1,5	1,5	2	2	1,5	no evaluation	3
	Overall evaluation of Science-based Criteria	Human Toxicity	2	2	2	2,5	3	3	5	3
	Stakeholder Acceptance	Human Toxicity	1,5	2	3	2	3	2	no evaluation	3
		Summe	11	13	13	15	17,5	13	not complete	21

Online Plus Material

Tabelle 4 — Bewertung der Methoden zur Erfassung der Wirkungskategorie Respiratory Inorganics

			Methode								
Quelle	**Prüfindikator**	**Wirkungskategorie**	USEtox intake fraction	IMPACT 2002+ intake fraction	Humbert et al. 2009 intake & uptake fraction, endpoint	Hofstetter 1998 intake fraction, endpoint	Greco et al. 2007 intake fraction	Risk Poll intake fraction, endpoint, CBA	TRACI intake fraction, endpoint	van Zelm et al. 2008 intake fraction, endpoint	Ecosense intake fraction, endpoint, CBA
Joint Research Centre (2011, S. 33 ff.)	Scope	Respiratory Inorganics	3	3	4	3	3,5	2	3	3	1
	Relevance	Respiratory Inorganics	3	3	3	3	3,5	2	3	3	2
	Robustness & Certainty	Respiratory Inorganics	3	3	2	3	3,5	2	2	2	2
	Documentation, Transparency & Reproducibility	Respiratory Inorganics	1	2	4	2	2	2	2	2	2
	Applicability	Respiratory Inorganics	2	2	2	1	3	2	1	1	1
	Overall evaluation of Science-based Criteria	Respiratory Inorganics	3	3	3	3	2	2	2	2	2
	Stakeholder Acceptance	Respiratory Inorganics	2	3	4	2	3,5	3	2	2	2
		Summe	17	19	22	17	21	15	15	15	12

Tabelle 5 — Bewertung der Methoden zur Erfassung der Wirkungskategorie Ionizing Radiation

			Methode	
Quelle	**Prüfindikator**	**Wirkungskategorie**	Frischknecht et al. 2000 human health	Garnier-Laplace et al. 2008 & 2009
Joint Research Centre (2011, S. 42 ff.)	Scope	Ionizing Radiation	no evaluation	2
	Relevance	Ionizing Radiation	2	2
	Robustness & Certainty	Ionizing Radiation	2	2
	Documentation, Transparency & Reproducibility	Ionizing Radiation	1	3
	Applicability	Ionizing Radiation	2	2
	Overall evaluation of Science-based Criteria	Ionizing Radiation	2	2
	Stakeholder Acceptance	Ionizing Radiation	3	3
		Summe	no complete evaluation	16

Tabelle 6 — Bewertung der Methoden zur Erfassung der Wirkungskategorie Photochemical Ozone Formation

			Methode									
Quelle	**Prüfindikator**	**Wirkungskategorie**	CML 2002	EDIP 2003	LIME midpoint	MEEuP	ReCiPe midpoint	ReCiPe endpoint	TRACI midpoint	EcoSense endpoint	EPS2000 endpoint	LIME endpoint
Joint Research Centre (2011, S. 47 ff.)	Scope	Photochemical Ozone Formation	2,5	2	2	3	1,5	2	2	1,5	2	2
	Relevance	Photochemical Ozone Formation	2,5	1,5	2	no evaluation	3	2	2,5	2	2	2
	Robustness & Certainty	Photochemical Ozone Formation	2,5	2	4	no evaluation	2,5	2,5	3	2	3,5	2,5
	Documentation, Transparency & Reproducibility	Photochemical Ozone Formation	3	2,5	2,5	no evaluation	2	2	3	2	2	2,5
	Applicability	Photochemical Ozone Formation	1	1	2	no evaluation	1,5	1,5	1	1,5	1,5	2
	Overall evaluation of Science-based Criteria	Photochemical Ozone Formation	2,5	2	2,5	no evaluation	2	2	2,5	2	2,5	2,5
	Stakeholder Acceptance	Photochemical Ozone Formation	2,5	2,5	2,5	1	2,5	2,5	2	2	2,5	2,5
		Summe	16,5	13,5	17,5	no complete evaluation	15	14,5	16	13	16	16

Tabelle 7 — Bewertung der Methoden zur Erfassung der Wirkungskategorie Acidification

			Methode									
Quelle	**Prüfindikator**	**Wirkungskategorie**	TRACI	EDIP	MeeuP	Accumulated Exceedence	CML 2002	ReCiPe midpoint	ReCiPe endpoint	LIME midpoint	LIME endpoint	EcoIndicator99
Joint Research Centre (2011, S. 55 ff.)	Scope	Acidification	2,5	4	3	2	2	2,5	2,5	2	2,5	3
	Relevance	Acidification	3	4	5	1	2	2	2	4	2	3
	Robustness & Certainty	Acidification	2	no evaluation	no evaluation	2	2,5	2,5	2,5	no evaluation	3	3
	Documentation, Transparency & Reproducibility	Acidification	4	3	no evaluation	2	2	2,5	2	no evaluation	2,5	3
	Applicability	Acidification	no evaluation	no evaluation	no evaluation	1	1	1	1	no evaluation	1	1
	Overall evaluation of Science-based Criteria	Acidification	5	5	5	1,5	2	2	2,5	5	2,5	3
	Stakeholder Acceptance	Acidification	no evaluation	no evaluation	no evaluation	2	3	3,5	3,5	3	2,5	3
		Summe	no complete evaluation	16	no complete evaluation	11,5	14,5	16	16	no complete evaluation	16	19

Tabelle 8 — Bewertung der Methoden zur Erfassung der Wirkungskategorie Aquatic Eutrophication

			Methode								
Quelle	**Prüfindikator**	**Wirkungskategorie**	CML 2002	EDIP 2003 aquatic	LIME midpoint	ReCiPe midpoint	ReCiPe endpoint	LIME endpoint	TRACI	EPS 2000 endpoint	IMPACT 2002+ endpoint
Joint Research Centre (2011, S. 65 ff.)	Scope	Aquatic Eutrophication	2,5	1,5	3	2	2	3	2,5	1,5	2,5
	Relevance	Aquatic Eutrophication	4,5	1,5	2,5	1,5	1,5	2	1,5	3	4,5
	Robustness & Certainty	Aquatic Eutrophication	4,5	2	3	2	2	2,5	2,5	2,5	3,5
	Documentation, Transparency & Reproducibility	Aquatic Eutrophication	1	2	2,5	2	2	2,5	3	2	2
	Applicability	Aquatic Eutrophication	1	1	1	1	1,5	1	1	2	1
	Overall evaluation of Science-based Criteria	Aquatic Eutrophication	2,5	2	2	2	2	2	2	2,5	2,5
		Summe	18,5	12	17	13	14	15,5	14,5	17,5	19

Tabelle 9 — Bewertung der Methoden zur Erfassung der Wirkungskategorie Terrestrical Eutrophication

			Methode				
Quelle	**Prüfindikator**	**Wirkungskategorie**	Accumulated Exceedence	CML 2002	EDIP 2003 terrestrial	EPS 2000	EcoIndica-tor99 endpoint
Joint Research Centre (2011, S. 65 ff.)	Scope	Terrestrial Eutrophication	1,5	2,5	2,5	1,5	2,5
	Relevance	Terrestrial Eutrophication	1,5	4,5	2,5	3	2
	Robustness & Certainty	Terrestrial Eutrophication	2	4,5	2	2,5	3
	Documentation, Transparency & Reproducibility	Terrestrial Eutrophication	2,5	1	2,5	2	2,5
	Applicability	Terrestrial Eutrophication	1	1	1	2	1
	Overall evaluation of Science-based Criteria	Terrestrial Eutrophication	1	2,5	2	2,5	2,5
		Summe	11,5	18,5	15	17,5	17

Tabelle 10 — Bewertung der Methoden zur Erfassung der Wirkungskategorie Ecotoxicity

			Methode						
Quelle	**Prüfindikator**	**Wirkungskategorie**	USEtox midpoint	ReCiPe midpoint	IM-PACT2002+	TRACI midpoint	EDIP 2003 midpoint	Swiss Ecoscarcity midpoint	MEEuP midpoint
Joint Research Centre (2011, S. 78 ff.)	Scope	Ecotoxicity	1	1,5	1,5	1,5	1,5	5	5
	Relevance	Ecotoxicity	2,5	2	1,5	2	2,5	5	5
	Robustness & Certainty	Ecotoxicity	2	2	2	2	3,5	no evaluation	no evaluation
	Documentation, Transparency & Reproducibility	Ecotoxicity	1	1	1	1	1	no evaluation	no evaluation
	Applicability	Ecotoxicity	2,5	1	1,5	2	2	no evaluation	no evaluation
	Overall evaluation of Science-based Criteria	Ecotoxicity	2	2	2	2	3	5	5
	Stakeholder Acceptance	Ecotoxicity	1,5	2	2,5	2	3	no evaluation	no evaluation
		Summe	12,5	11,5	12	12,5	16,5	no complete evaluation	no complete evaluation

Tabelle 11 — Bewertung der Methoden zur Erfassung der Wirkungskategorie Ecotoxicity

			Methode		
Quelle	**Prüfindikator**	**Wirkungskategorie**	EPS 2000 endpoint	ReCiPe endpoint	IM-PACT2002+ endpoint
Joint Research Centre (2011, S. 78 ff.)	Scope	Ecotoxicity	1	1,5	1,5
	Relevance	Ecotoxicity	5	3	3
	Robustness & Certainty	Ecotoxicity	no evaluation	4	5
	Documentation, Transparency & Reproducibility	Ecotoxicity	no evaluation	1	1
	Applicability	Ecotoxicity	no evaluation	1	1,5
	Overall evaluation of Science-based Criteria	Ecotoxicity	5	4	4
	Stakeholder Acceptance	Ecotoxicity	no evaluation	3	2
		Summe	no complete evaluation	17,5	19

Tabelle 12 — Bewertung der Methoden zur Erfassung der Wirkungskategorie Land Use

			Methode							
Quelle	**Prüfindikator**	**Wirkungskategorie**	ReCiPe midpoint	Baitz 2002 further developed by Bos & Wittstock 2008	Milà i Canals et al. 2007b	ReCiPe endpoint	EcoIndica-tor99 endpoint	EPS 2000 endpoint	LIME endpoint	Swiss Ecoscarcity endpoint
Joint Research Centre (2011, S. 84 ff.)	Scope	Land Use	5	2	3	3	3	4	4	3
	Relevance	Land Use	5	3	3	3	4	4	3	4
	Robustness & Certainty	Land Use	no evaluation	2	1	3	3	3	5	2
	Documentation, Transparency & Reproducibility	Land Use	no evaluation	4	1	1	1	1	5	1
	Applicability	Land Use	no evaluation	5	5	2	2	2	4	2
	Overall evaluation of Science-based Criteria	Land Use	5	4	3	3	4	4	4	3
	Stakeholder Acceptance	Land Use		5	4	3	3	3	3	3
		Summe	no complete evaluation	24	19	18	20	21	28	18

Tabelle 13 — Bewertung der Methoden zur Erfassung der Wirkungskategorie Resource Depletion

			Methode									
Quelle	**Prüfindikator**	**Wirkungskategorie**	Exergy Category 1 midpoint	Swiss Ecoscarcity Category 1 midpoint	CML 2002 Category 1 midpoint	EDIP 2003 Category 2 midpoint	MEEuP Category 3 midpoint	Swiss Ecoscarcity Water Category 3 midpoint	EPS 2000 Category 4 endpoint	ReCiPe Category 4 endpoint	EcoIndica-tor99 Category 4 endpoint	IMPACT 2002+ Category 4 endpoint
Joint Research Centre (2011, S. 92 ff.)	Scope	Resource Depletion	1	3	3	3	5	3	1	2	2	2
	Relevance	Resource Depletion	3	3	2	3	4	2	2	3	4	4
	Robustness & Certainty	Resource Depletion	2	5	2	3	5	3	3	2	3	4
	Documentation, Transparency & Reproducibility	Resource Depletion	1	2	1	1	1	2	1	1	1	1
	Applicability	Resource Depletion	1	1	1	1	1	2	2	2	2	2
	Overall evaluation of Science-based Criteria	Resource Depletion	2	3	2	2	4	2	3	2	3	3
	Stakeholder Acceptance	Resource Depletion	3	4	2	2	5	2	3	3	3	3
		Summe	13	21	13	15	25	16	15	15	18	19

B Überblick sozial-nachhaltiger Midpointindikatoren

Tabelle 14 — Überblick sozial-nachhaltiger Midpointindikatoren - Nr. 1-8

No.	Source	Stakeholder	Indicator (acc. to Source)	Midpoint Category	Product Life Cycle Phase	Quantitative data availability (acc. to Source)	Assigned Midpoint Category (defined for Thesis)	Attribute of Product (defined for Thesis)	Comment	Indicator is selected for model
1	Schmidt et al. (2004)	Employees	working accidents	human health	production and disposal	yes	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen		yes
2	Schmidt et al. (2004)	Employees	fatal occupational and commuting accidents	human health	production and disposal	yes	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen		yes
3	Schmidt et al. (2004)	Employees	occupational diseases	human health	production and disposal	yes	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen		yes
4	Schmidt et al. (2004)	Employees	wages and salaries	work/ working conditions	production and disposal	yes	n/a	n/a	monetary added value difficult to integrate	no
5	Schmidt et al. (2004)	Employees	company benefits such as housing subsidies, workforce facilities, payments in kind and cafeteria subsidies	work/ working conditions	production and disposal	yes	n/a	n/a		no
6	Schmidt et al. (2004)	Employees	expenditures for professional training and continuing education	education and research	production and disposal	yes	Produktverantwor-tung	Die Erhöhung der Transparenz bei der produktbezogenen Kommunikation	monetary added value difficult to integrate	no
7	Schmidt et al. (2004)	Employees	strikes and lockouts	work/ working conditions	production and disposal	yes	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen	indicator for inappropriate circumstances	yes
8	Schmidt et al. (2004)	Suppliers/ business partners	freedom of association	work/ working conditions	production	no	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen	basis for strike / stoppages	yes

Tabelle 15 — Überblick sozial-nachhaltiger Midpointindikatoren - Nr. 9-15

No.	Source	Stakeholder	Indicator (acc. to Source)	Midpoint Category	Product Life Cycle Phase	Quantitative data availability (acc. to Source)	Assigned Midpoint Category (defined for Thesis)	Attribute of Product (defined for Thesis)	Comment	Indicator is selected for model
9	Schmidt et al. (2004)	Suppliers/ business partners	discrimination	work/ working conditions	production	no	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen	basis for health related indicator - occupational diseases	yes
10	Schmidt et al. (2004)	Suppliers/ business partners	forced labour	work/ working conditions	production	no	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen		yes
11	Schmidt et al. (2004)	Suppliers/ business partners	child labor	work/ working conditions	production	no	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen		yes
12	Schmidt et al. (2004)	End customers	toxicity potential	human health	use	no	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen		yes
13	Schmidt et al. (2004)	End customers	additional health risks (e.g. danger of accidents, addiction)	human health	use	no	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen		yes
14	Schmidt et al. (2004)	End customers	extra benefits than enhance customer satisfaction (e.g. service, increase in leisure time, low noise)	living conditions	use	no	n/a	n/a		no
15	Schmidt et al. (2004)	End customers	Completeness and quality of product information (origin, ingredients, use, potential dangers, side-effects etc.)	CSR	use	no	Produktverantwortung	Die Erhöhung der Transparenz bei der produktbezogenen Kommunikation		yes

Tabelle 16 — Überblick sozial-nachhaltiger Midpointindikatoren - Nr. 16-24

No.	Source	Stakeholder	Indicator (acc. to Source)	Midpoint Category	Product Life Cycle Phase	Quantitative data availability (acc. to Source)	Assigned Midpoint Category (defined for Thesis)	Attribute of Product (defined for Thesis)	Comment	Indicator is selected for model
16	Schmidt et al. (2004)	End customers	consumer labels (e.g. textile confidence label)	CSR	use	no	Produktverantwor-tung	Die Erhöhung der Transparenz bei der produktbezogenen Kommunikation		yes
17	Schmidt et al. (2004)	Neighbourhood and society	Number of employees	work/ working conditions	production and end of life	yes	n/a	n/a	no direct dependency	no
18	Schmidt et al. (2004)	Neighbourhood and society	Number of unskilled workers (qualification of employees)	work/ working conditions	production and end of life	yes	n/a	n/a	no direct dependency	no
19	Schmidt et al. (2004)	Neighbourhood and society	number of female managers	work/ working conditions	production and end of life	yes	n/a	n/a	no direct dependency	no
20	Schmidt et al. (2004)	Neighbourhood and society	number of disabled employees	work/ working conditions	production and end of life	yes	n/a	n/a	no direct dependency	no
21	Schmidt et al. (2004)	Neighbourhood and society	number of part-time workers	work/ working conditions	production and end of life	yes	n/a	n/a	no direct dependency	no
22	Schmidt et al. (2004)	Neighbourhood and society	company expenditures for family support	work/ working conditions	production and end of life	yes	n/a	n/a		no
23	Schmidt et al. (2004)	Neighbourhood and society	benefits for disadvantaged people (e.g. diabled, sick, poor) due to product qualities	CSR	use	no	Produktverantwor-tung	Erhöhung der Systemfunktionalität	inherent nature of Healthcare products	yes
24	Schmidt et al. (2004)	Neighbourhood and society	violation of ethical norms due to product use or advertisement	CSR	use	no	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen	psychosocial risks	yes

Tabelle 17 — Überblick sozial-nachhaltiger Midpointindikatoren - Nr. 25-33

No.	Source	Stakeholder	Indicator (acc. to Source)	Midpoint Category	Product Life Cycle Phase	Quantitative data availability (acc. to Source)	Assigned Midpoint Category (defined for Thesis)	Attribute of Product (defined for Thesis)	Comment	Indicator is selected for model
25	Schmidt et al. (2004)	Neighbourhood and society	potential misuse of products (e.g. as weapon)	CSR	use	no	Produktverantwor-tung	Erhöhung der Systemfunktionalität		yes
26	Schmidt et al. (2004)	Neighbourhood and society	potential of intensification of social an political conflicts (e.g. due to changes of traditional life styles)	CSR	use	no	Produktverantwor-tung	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen	adds to ”violation of ethical norms”in no. 24	no
27	Schmidt et al. (2004)	Future generations	number of trainees	education and research	production and end of life	yes	n/a	n/a	no direct dependency	no
28	Schmidt et al. (2004)	Future generations	expenditures for R&D	education and research	production and end of life	yes	n/a	n/a	monetary added value difficult to integrate	no
29	Schmidt et al. (2004)	Future generations	capital investment	living conditions	production and end of life	yes	n/a	n/a	monetary added value difficult to integrate	no
30	Schmidt et al. (2004)	Future generations	company expenditures for social security	CSR	production and end of life	yes	n/a	n/a	monetary added value difficult to integrate	no
31	Schmidt et al. (2004)	International community	imports from developing countries	CSR	production	n/a	n/a	n/a	no direct dependency	no
32	Schmidt et al. (2004)	International community	sum of import duties and export subsidies (protectionism)	CSR	production	n/a	n/a	n/a	not relevant in this context	no
33	Schmidt et al. (2004)	International community	fair trade labels, etc.	CSR	production	no	n/a	Die Erhöhung der Transparenz bei der produktbezogenen Kommunikation	product information;indicator for compliance; self-assessment	yes

Tabelle 18 — Überblick sozial-nachhaltiger Midpointindikatoren - Nr. 34-40

No.	Source	Stakeholder	Indicator (acc. to Source)	Midpoint Category	Product Life Cycle Phase	Quantitative data availability (acc. to Source)	Assigned Midpoint Category (defined for Thesis)	Attribute of Product (defined for Thesis)	Comment	Indicator is selected for model
34	Mazijn et al. (2004)	Employees	freedom of association and collective bargaining (ILO conventions C87, C98, C135)	work/ working conditions	production	n/a	n/a	n/a		no
35	Mazijn et al. (2004)	Employees	forced and compulsory labour (C29, C105)	work/ working conditions	production	n/a	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen	covered in no. 10 forced labor”	no
36	Mazijn et al. (2004)	Employees	child labour (C138, C182)	work/ working conditions	production	n/a	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen	covered in no. 11 child labor”	no
37	Mazijn et al. (2004)	Employees	wages (C26, C131)	work/ working conditions	production	n/a	n/a	n/a	no direct dependency	no
38	Mazijn et al. (2004)	Employees	working hours (C130)	work/ working conditions	production	n/a	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen	impact on heath of employees	yes
39	Mazijn et al. (2004)	Employees	decent working conditions - harsh or inhumane treatment, physical abuse, theats of physical abuse, unusual punishments or discipline, sexual and or harassment, intimidation by the employer violations	human health	production	n/a	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen	covered in no. 24 ”violation of ethical norms”	no
40	Mazijn et al. (2004)	Employees	occupational health and safety (C155)	human health	production	n/a	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen		yes

Tabelle 19 — Überblick sozial-nachhaltiger Midpointindikatoren - Nr. 41-46

No.	Source	Stakeholder	Indicator (acc. to Source)	Midpoint Category	Product Life Cycle Phase	Quantitative data availability (acc. to Source)	Assigned Midpoint Category (defined for Thesis)	Attribute of Product (defined for Thesis)	Comment	Indicator is selected for model
41	Mazijn et al. (2004)	End customers	recognised employment relationships and social security	CSR	production	n/a	Produktverantwor-tung	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen		no
42	Mazijn et al. (2004)	regional / national legislation	compliance with legislation; company compliance with national and regional env., economic and social legislation	CSR- integrated aspects	production	n/a	Produktverantwor-tung	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen		yes
43	Mazijn et al. (2004)	End customers	quality and durability- product is of good quality compared to non-labelled goods	CSR- integrated aspects	use	n/a	Produktverantwor-tung	Systemfunktionalität		yes
44	Mazijn et al. (2004)	End customers	management strategies and policies- clear social policy guidelines are present	CSR- integrated aspects	production	n/a	Produktverantwor-tung	Die Erhöhung der Transparenz bei der produktbezogenen Kommunikation	ensure implementation of requirements during product design	yes
45	Mazijn et al. (2004)	End customers	management strategies and policies- environmental policy with clear guidelines is present and publicly available	CSR- integrated aspects	production	n/a	n/a	n/a		no
46	Mazijn et al. (2004)	End customers	management system - a person is responsible for the implementation of social principles	integrated aspects	production	n/a	Produktverantwor-tung	Die Erhöhung der Transparenz bei der produktbezogenen Kommunikation	ensure implementation of requirements during product design	yes

Tabelle 20 — Überblick sozial-nachhaltiger Midpointindikatoren - Nr. 47-54

No.	Source	Stakeholder	Indicator (acc. to Source)	Midpoint Category	Product Life Cycle Phase	Quantitative data availability (acc. to Source)	Assigned Midpoint Category (defined for Thesis)	Attribute of Product (defined for Thesis)	Comment	Indicator is selected for model
47	Mazijn et al. (2004)	End customers	management system - a person is responsible for the implementation of environmental principles	integrated aspects	production	n/a	n/a	n/a		no
48	Mazijn et al. (2004)	End customers	management system - the company measures the realisation of the social objectives	integrated aspects	production	n/a	Produktverantwor-tung	Die Erhöhung der Transparenz bei der produktbezogenen Kommunikation	ensure implementation of requirements during product design	yes
49	Mazijn et al. (2004)	End customers	management system - the company measures the realisation of the environmental objectives	integrated aspects	production	n/a	n/a	n/a	environmental assessment	no
50	Dreyer et al. (2006)	Employees	occupational health and safety impacts	n/a	production and end of life	n/a	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen	covered in no. 40 "occupational health and safety"	no
51	Dreyer et al. (2006)	Employees	injection of capital in local community in a developing country	human society		n/a	n/a	n/a	monetary added value difficult to integrate	no
52	Dreyer et al. (2006)	Employees	job creation	human society		n/a	n/a	n/a	economic factor	no
53	Dreyer et al. (2006)	Employees	indecent working conditions	human society		n/a	Physische Arbeitsbedingungen	Min des Risikos beim Kontakt des Produktsystems mit dem Menschen	covered in no. 1-3	no
54	Dreyer et al. (2006)	Employees	exploitation of local natural resources	human society		n/a	Produktverantwor-tung	n/a	intergenerational justice - directly linked to product responsibility	yes

C | Limited substances – stoffbasierte Risikoanalyse für komplexe Medizinprodukte

Color coding:	
not significant	green
low significance	light yellow
medium significance	yellow/orange
high significance	red

Limited Materials

	Substance group	Substance details	Periodic table subgroup	Coverage (estimated time of sourcing availability of substance); availability	Political stability of sourcing region other dangers (environment/ health)	3-country concentration (share of three largest sourcing countries of world production of substance)
Metals	Alkalimetals	Cesium (Cs)		World resources of cesium have not been estimated. Cesium is associated with lithium-bearing pegmatites worldwide [1]	There are no known human health issues associated with cesium, and its use has minimal environmental impact [1] Zimbabwe is political insecure [2]	Cesium resources have been identified in Canada, Namibia and Zimbabwe. Smaller concentrations are also known in brines in Chile and China and in geothermal systems in Germany, India [1]
Metals	Alkalimetals	Lithium (Li)		Contradicting research results. Resources are safe for upcoming years. Recycling rate needs to be improved [3]	Main resources stem from South Africa, therefore strong dependency from South Africa. Chile and Argentina are main shareholders with more than 50% on mines [3]	Bolivia, Brazil, China, Argentina, Kongo, Serbia, Australia, Canada [1]
Metals	Alkalimetals	Sodium (Na)	Sodium Sulfate	Data on mine production for natural sodium sulfate are not available, total world production of natural sodium sulfate is estimated to be about 6 million tons [1]	Inner political conflict in Egypt [2]	Botswana, China, Egypt, Italy, Mongolia, Romania, and South Africa, USA [1]
Metals	Alkalimetals	Potassium (K)		atificial production from pot ashes. Naturally available minerals containing K are: Sylvin, Carnallit, Schönit, Polyhalit, Orthoklas, Muskovit; 2,5 % constituent of the lithosphere [1]	widespread deposit in several minerals [1]	Producers of Pottattium chloride: China, USA, Germany; Producers of potash: Canada, Russia, Belrus [1]
Metals	Alkalimetals	Rubidium (Rb)		World resources of rubidium are unknown [1]	No risks known [1]	Several significant rubidium-bearing zoned pegmatites in Canada, pegmatite occurrences in Afghanistan, Namibia, Peru, Russia, and Zambia. Minor amounts of rubidium can be found in brines in northern Chile and China and in evaporites in France, Germany, and the United States [1]
Metals	Alkalimetals	Francium (Fr)		Francium is extremely rare. Because of this its chemical and physical properties are not known. here's no reason to study its effects on human health. [4]		
Metals	Alkaline earth metals	Magnesium (Mg)		The reserves for this metal are sufficient to supply current and future requirements. Resources from which magnesium may be recovered range from large to virtually unlimited and are globally widespread. Resources of dolomite and magnesium-bearing evaporite minerals are enormous. Magnesium-bearing brines are estimated to constitute a resource in the billions of tons, and magnesium can be recovered from seawater at places along world coastlines [1]	No risks known [1]	China, Austria, Canada, Brazil, USA [1]
Metals	Alkaline earth metals		Mag-nesium com-pounds	Resources from which magnesium compounds can be recovered range from large to virtually unlimited and are globally widespread [1]	No dangers known.Resources from which magnesium compounds can be recovered range from large to virtually unlimited and are globally widespread. Identified world resources of magnesite total 12 billion tons, and of brucite, several million tons. Resources of dolomite, forsterite, magnesium-bearing evaporite minerals, and magnesia-bearing brines are estimated to constitute a resource in billions of tons. Magnesium hydroxide can be recovered from seawater [1]	Canada, Israel, China, Russia, USA [1]
Metals	Alkaline earth metals	Beryllium (Be)		World resources in known deposits of beryllium have been estimated to be more than 80,000 tons. About 65% of these resources is in nonpegmatite deposits in the United States—the Gold Hill and Spor Mountain areas in Utah and the Seward Peninsula area in Alaska account for most of the total [1]	Because of the toxic nature of beryllium, various international, national, and State guidelines and regulations have been established regarding beryllium in air, water, and other media. Industry is required to carefully control the quantity of beryllium dust, fumes, and mists in the workplace, which adds to the final cost of beryllium products [1] Sea transportation of material from Mozambique is endangered because of piracy [2]	USA (89%), China, Mozambique [1]
Metals	Alkaline earth metals	Calcium (Ca)		Calcium is the fifth element and the third most abundant metal in the earth's crust [4]	widespread deposit in several minerals, no dangers known [1]	
Metals	Alkaline earth metals	Strontium (Sr)		World resources of strontium are thought to exceed 1 billion tons [1]	widespread deposit in several minerals; Iran with high conflict potential and UN-embargo [2]	China, Spain, Mexico, Iran [1]
Metals	Alkaline earth metals	Barium (Ba)		Barium normally bonded in Wintherite (barium charbonate) or Barite. Barite production 2006 7.960.000 t [5]	widespread deposit in several countries [1]	in Barite: Germand, USA, China, Mexiko and India in Witherithe: England, Germany [18]
Metals	Alkaline earth metals	Radium (Ra)		The amount of radium in uranium ores varies between 150 and 350 mg/ton. [4] One of the most abundant elements in the earth crust [18]	DR Congo and Canada are the main producer. [4] DR Congo is a continuing high conflict region [2] High cancer risk [18]	Canada, DR Congo [4]
Metals	Transition metals (Rare Earths)	Scandium (Sc)		A supply shortage is not to be expected for scandium according to the German Federal Institute for Geosciences and Natural Resources [7] Mine production data were not available. Scandium is rarely concentrated in nature because of its lack of affinity for the common ore-forming anions. It is widely dispersed in the lithosphere and forms solid solutions in more than 100 minerals. Undiscovered scandium resources are thought to be very large [1]	Madagasgar is a confict region with a inner political crises since 2009 [2]	Australia, China, Kazakhstan, Madagascar, Norway, Russia, and Ukraine [1]

Significance for technologies	Risk of strategic use of substance (trade and competition risks); cost-risk	Substitutability, replaceability
Atomic clocks, global positioning satellite, Internet, cell phone transmissions, aircraft guidances systems; cesium-131 and cesium-137 are primarily used to treat cancer; industrial gauges, mining and geophysical instruments, seterilization of food, sewage, surgical equipment, ferrous and nonferrous metallurgy [1]	Commercially useful quantities of inexpensive cesium are available as a byproduct of the production of lithium. Increases in lithium exploration are expected to yield discoveries of additional cesium resources, which may lead to expanded commercial applications [1]	Iodine-125 and palladium-103 are substitues for cesium-137 in the treatment of prostate cancer [1] Cesium and rubidium can be used interchangeably in many applications because they have similar physical properties and atomic radii. Cesium, however, is more electropositive than rubidium, making it a preferred material in many applications [1]
Highly significant for accumulators and batteries, metallurgy, reator technology, chemicals, glas [9] ceramics and glass;batteries; lubricating greases, air treatment, primary aluminum production; continuous casting; rubber and thermoplastics; pharmaceuticals [1]	Lithium is produced as a side product of calcium and other fertilizers. If the resources demand of lithium as a side product will be exceeded, there will be a significant cost increase. The production is energy-intensive and requires costly transportation processes [3].	Substitution for lithium compounds is possible in batteries, ceramics, greases, and manufactured glass. Examples are calcium and aluminum soaps as substitutes for stearates in greases; calcium, magnesium, mercury, and zinc as anode material in primary batteries; and sodic and potassic fluxes in ceramics and glass manufacture. Lithium carbonate is not considered to be an essential ingredient in aluminum potlines. Substitutes for aluminum lithium alloys in structural materials are composite materials consisting of boron, glass, or polymer fibers in engineering resins [1]
Soap and detergents; glass, pulp and paper, carpet fresheners and textiles [1]	Sodium sulfate resources are sufficient to last hundreds of years at the present rate of world consumption [1]	In pulp and paper, emulsified sulfur and caustic soda (sodium hydroxide) can replace sodium sulfate. In detergents, a variety of products can substitute for sodium sulfate. In glassmaking, soda ash and calcium sulfate have been substituted for sodium sulfate with less-effective results [1]
	Potash world resources about 250 billion tons [1]	Natrium can replace Potassium as metal [1]
Biomedical research, electronics, specialty glass, and pyrotechnics. Biomedical applications include rubidium salts used in the treatment of epilepsy and rubidium-82 used as a blood-flow tracer. Rubidium is used as an atomic resonance frequency standard in atomic clocks, playing a vital role in global positioning systems (GPS). Rubidium-rich feldspars are used in ceramic applications for spark plugs and electrical insulators because of their high-dielectric capacity [1]	One mine in Canada produced rubidium ore which was converted to byproduct concentrate. Part of that concentrate was then exported to the United States for further processing. Production data from the Canadian mine, and U.S. consumption, export, and import data, are not available [1]	Rubidium and cesium have similar physical properties and may be used interchangeably in many applications; however, cesium is a preferred material in many applications because it is more electropositive than rubidium [1]
No use has been found for what little francium can be produced [4]		
It has countless applications in cases where weight reducing is important, i.e. in aeroplane and missile construction. It also has many useful chemical and metallurgic properties, which make it appropriate for many other non-structural applications. Magnesium components are widely used in industry and agriculture. Other uses include: removal of sulphur form iron and steel, photoengraved plates in the printing industry; reducing agent for the production of pure uranium and other metals from their salts; flashlight photography, flares, and pyrotechnics. [4] Aluminum-based alloys that were used for packaging, transportation, and other applications was the leading use for primary magnesium, accounting for 41% of primary metal use [1]	No risks known [1]	Aluminum and zinc may substitute for magnesium in castings and wrought products. For iron and steel desulfurization, calcium carbide may be used instead of magnesium [1]
The metal is used in aluminium alloys for bearings, as a helper in the bismuth removal form lead, as well as in controlling graphitic carbon in melted iron. It is also used as a deoxidizer in the manufacture of many steels; as a reducing agent in the preparation of metals as chromium, thorium, zirconium and uranium, and as separating material for gaseous mixtures of nitrogen and argon. Calcium is an alloying used in the production of alluminium, beryllium, copper, lead and magnesium alloys. It is also used in making cements and mortar that are used in builldings [4] Used in agricultural, chemical, construction, environmental, and industrial applications, refractories [1]	No risks known [1]	Alumina, chromite, and silica substitute for magnesia in some refractory applications [1]
Computer and telecommunications products, aerospace and defense applications, appliances, automotive electronics, industrial components, medical devices [1]	Cost of the metal is caused by the high level of regulatory and health burden the substance causes [1]	Because the cost of beryllium is high compared with that of other materials, it is used in applications in which its properties are crucial. In some applications, certain metal matrix or organic composites, high-strength grades of aluminum, pyrolytic graphite, silicon carbide, steel, or titanium may be substituted for beryllium metal or beryllium composites. Copper alloys containing nickel and silicon, tin, titanium, or other alloying elements or phosphor bronze alloys (copper-tin-phosphorus) may be substituted for beryllium-copper alloys, but these substitutions can result in substantially reduced performance. Aluminum nitride or boron nitride may be substituted for beryllium oxide in some applications [1]
the demand on Calcium is insignificant [5]	the demand on Calcium is insignificant [5]	
Pyrotechnics and signals, ferrite ceramic magnets; master alloys; pigments and fillers, electrolytic production of zinc [1] nuclear medicine, high-temperature supercontuctor, infrared-detectors [6]	the demand on Strontium is insignificant [5]	Barium can be substituted for strontium in ferrite ceramic magnets; however, the resulting barium composite will have a reduced maximum operating temperature when compared with that of strontium composites. Substituting for strontium in pyrotechnics is hindered because of the difficulty in obtaining the desired brilliance and visibility imparted by strontium and its compounds [1]
Barite is used as a weighting agent in gas- and oil-well drilling fluids, also used as aggregate in high-density concrete for radiation shielding (x-ray units, nuclear powerplants, nuclear research facilities). Ultrapure baite used as a contrast medium in x-ray examinations [1]	Identified resources worldwide 720 million tons (2 billion tons unindentified) the demand on Barite depends on the oil- and gasdrilling market, deepwater drilling uses more Barite [1]	In the drilling mud market, alternatives to barite include celestite, ilmenite, iron ore, and synthetic hematite that is manufactured in Germany. None of these substitutes, however, has had a major impact on the barite drilling mud industry [1]
Radium is used in medicine to produce radon gas (cancer treatment) [4]	Radioactive substance (use and disposal costs at eol) [Expert Judgement]	Hematite that is manufactured in Germany. None of these substitutes, however, has had a major impact on the barite [4]
Scandium-aluminium alloys are a suitable material for light weight construction. Due to the limited availability, it is mainly used in military aviation and not disseminated in civil aviation [8] Highly significant for airplane construction, mercury vapour lamps [9] Aluminum alloys for sporting equipment (baseball and softball bats, bicycle frames, crosse handles (lacrosse stick handles), golf clubs, gun frames, and tent poles), metallurgical research, high-intensity metal halide lamps, analytical standards, electronics, oil well tracers, and lasers. Future development of alloys for aerospace and specialty markets is expected [1]	The supply of scandium is stable with increased prices in 2010 [1]	

	Substance group	Substance details	Periodic table subgroup	Coverage (estimated time of sourcing availability of substance); availability	Political stability of sourcing region other dangers (environment/ health)	3-country concentration (share of three largest sourcing countries of world production of substance)
Metals	Transition metals (Rare Earths)	Yttrium (Y)		Potential shortages might occur for lanthanum, yttrium and europium with a high degree of probability [8] Yttrium causes approx. 145 kg of CO2/ kg if modeled in a simplified life cycle and thus has the second hightest env. impact, therefore there is the highest leverage on env. improvement and lesser chemicals needs if Ytttrium can be recycled [10] Large resources of yttrium in monazite and xenotime are available worldwide in ancient and recent placer deposits, carbonatites, uranium ores, and weathered clay deposits (ionadsorption ore). Additional large subeconomic resources of yttrium occur in apatite-magnetite-bearing rocks, deposits of niobium-tantalum minerals, non-placer monazite-bearing deposits, sedimentary phosphate deposits, and uranium ores, especially those of the Blind River District near Elliot Lake, Ontario, Canada, which contain yttrium in brannerite, monazite, and uraninite. The world's resources are probably very large. Yttrium is associated with most rare-earth deposits. It occurs in various minerals in differing concentrations and occurs in a wide variety of geologic environments, including alkaline granites and intrusives, carbonatites, hydrothermal deposits, laterites, placers, and vein-type deposits [1]	Yttrium production and marketing within China continued to be competitive [1]	China, Japan, France, Austria, Canada [1]
Metals	Transition metals (Rare Earths)	Lathanoids	Lan-thanum (La)	Potential shortages might occur for lanthanum, yttrium and europium with a high degree of probability [8] The production of Ni-MH batteries for hybrid vehicles might become limited due to shortages in neodymium and lanthanum [8] Found with rare earths in monazite and bastnasite [16]	Lathanum and Prasedomium have relatively low CO2footprints if modeled in a simplified life cycle being sourced from Bayan Obo, approx 40 kg of CO2/ kg [10] Approx 90 % of the european imports stem from China [8] is low toxic but acid and poisonous for humans [18]	China, Bayan Obo mine [8] Primary mining areas are USA, Brazil, India, Sri Lanka, Australia [13]
Metals	Transition metals (Rare Earths)	Lathanoids	Praseo-dymium (Pr)	Shortages of rare earths for the production of permanent magnets in the short term, with a high degree of probability. The relevant elements are terbium, dysprosium, praseodymium and neodymium [8]	Lathanum and Prasedomium have relatively low CO2 footprints if modeled in a simplified life cycle being sourced from Bayan Obo, approx 40 kg of CO2/ kg [10]	99% produced in China [1] & [9]
Metals	Transition metals (Rare Earths)	Lathanoids	Neo-dymium (Nd)	Shortages of rare earths for the production of permanent magnets in the short term, with a high degree of probability. The relevant elements are terbium, dysprosium, praseodymium and neodymium [8] There will be likely shortfalls [11]	Neodymium and Cerium have similar CO2 footprints if modeled in a simplified life cycle, approx 70kg of CO2 per /kg [10]	China, France, Japan, Austria [1]
Metals	Transition metals (Rare Earths)	Lathanoids	Samarium (Sm)	2 million tons worldwide reserves, world production of samarium oxide 700 tons per year [4]	After civil war in 2009 is Sri Lanka political solid [2]	USA, China, Brazil, India, Australia Sri Lanka [4]
Metals	Transition metals (Rare Earths)	Lathanoids	Europium (Eu)	There will be likely shortfalls [11] Worldwide production is about 100 tons per year [15] Excavated out of Bastnaesite and Monazite [16] Potential shortages might occur for lanthanum, yttrium and europium with a high degree of probability [8]		The mineral bastnaesite is locaded in China, USA, Russia. The mineral monazite is located in China, USA, South Africa and India [5]
Metals	Transition metals (Rare Earths)	Lathanoids	Gado-linium (Gd)	World production about 4.500 tons [5]	Gadolinium has by far the highest environmental impact in terms of GHG and a simplified life cycle sourcing the material from Bayan Obo, it is almost 3times higher than Yttrium (approx 420 kg of CO2/kg REE) [10]	China, France, Japan, Austria [1]
Metals	Transition metals (Rare Earths)	Lathanoids	Cerium (Ce)	The worldproduction of Cer is about 9.400 tons per year [15]	Neodymium and Cerium have similar CO2 footprints if modeled in a simplified life cycle, approx 70kg of CO2 per /kg [10]	USA, Scandinavia, CIS-states, India, Southafrika, Congo [18]
Metals	Transition metals (Rare Earths)	Lathanoids	Ytterbium (Yb)	Worldwide production less than 100 tons per year, is locaded with other Lanthanoids in Ytterearth and Gadolinite [15]		
Metals	Transition metals (Rare Earths)	Lathanoids	Lutetium (Lu)	Very rare, only available in monazite [12] Proportion of 0,00007% on the lithosphere, found in Cerium-composition metal [18]		
Metals	Transition metals (Rare Earths)	Lathanoids	Thulium ('Tm)	World production less then 100 tons per year [15]		
Metals	Transition metals (Rare Earths)	Lathanoids	Holmium (Ho)	World production less than 100 tons per year [15]		
Metals	Transition metals (Rare Earths)	Lathanoids	Erbium (Er)	There will be likely shortfalls [11] World production less than 100 tons per year [15]		
Metals	Transition metals (Rare Earths)	Lathanoids	Terbium (Tb)	Shortages of rare earths for the production of permanent magnets in the short term, with a high degree of probability. The relevant elements are terbium, dysprosium, praseodymium and neodymium [8] there will be likely shortfalls [11] World production less than 100 tons per year [15]		

Significance for technologies	Risk of strategic use of substance (trade and competition risks); cost-risk	Substitutability, replaceability
High temperatures superconductor (HTS) rotors are developed with the basic HTS wire substrate nicket tungsten and Yttrium and silver [8] Angerer et al (2009) analyse an upcoming application: the use of yttrium-barium-copperoxide (YBCO) as high temperature super conductor of the second generation. Associated advantages of this application are lower costs and a potentially higher performance. A new technology still under development is the solid oxide fuel cell (SOFC) which is regarded as the most promising fuel cell technology. Yttrium is contained in the electrolyte, and electrodes with mischmetal containing rare earths might improve their performance and reduce their costs [8] Used for red color, fluorescent lamps, ceramics, metal alloy agents [11] Highly significant for reaktortechnology, magnets, metallurgy, fluorescent lights, and x-ray [9] Uses were in phosphors for color televisions and computer monitors, temperature sensors, trichromatic fluorescent lights, and x-ray-intensifying screens. Yttria-stabilized zirconia was used in alumina-zirconia abrasives, bearings and seals, high-temperature refractories for continuous-casting nozzles, jet-engine coatings, oxygen sensors in automobile engines, simulant gemstones, and wear-resistant and corrosion-resistant cutting tools. In electronics, yttrium-iron garnets were components in microwave radar to control high-frequency signals. Yttrium was an important component in yttriumaluminum- garnet laser crystals used in dental and medical surgical procedures, digital communications, distance and temperature sensing, industrial cutting and welding, nonlinear optics, photochemistry, and Photoluminescence. Yttrium also was used in heating-element alloys, high-temperature superconductors, and superalloys [1]	Magnetic cooling, wind turbines with hightemperature superconductors (containing yttrium) and efficient and cost-efficient fuel cells (containing yttrium and mischmetal) might suffer from supply constraints slowing down their future dissemination [8] Probable shortages for energy efficient lamps and displays are to be expected for yttrium and lathanum [8] Although reserves may be sufficient to satisfy near-term demand at current rates of production, economics, environmental issues, and permitting and trade restrictions could affect the mining or availability of many of the rare-earth elements, including yttrium [1] The highest criticality in terms of supply risk and the importance to clean energy production are the five REE dysprosium, neodymium, terbium, yttrium and europium, which are also seen as critical by Öko-Institut [8] China policy initiatives restrict the export of prices for Y rose dramatically from 2007-2011 [11]	Research activities are being undertaken which focus on yttrium and europium recovery from TV tubes and computer monitors [8] OSRAM holds a patent on the recycling of yttrium and europium from discharge lamps and fluorescent lamps [8] Substitutes for yttrium are available for some applications but generally are much less effective. In most uses, especially in electronics, lasers, and phosphors, yttrium is not subject to substitution by other elements. As a stabilizer in zirconia ceramics, yttria (yttrium oxide) may be substituted with calcia (calcium oxide) or magnesia (magnesium oxide), but they generally impart lower toughness [1]
In future, LEDs might eliminate the need for lanthanum and terbium phosphors while continuing use of cerium and europium. Future generations of OLEDs might even be free of all rare earths. lanthanum is crucial for FCC catalysts because it provides thermal stability and selectivity [8] One of the oldest applications is the use of cerium and lanthanum in pyrophoric alloys which are used in flint ignition devices for lighters and torches . Ni-MH batteries are used in hybrid electric vehicles and in portable appliances. Besides nickel and cobalt, they contain a mix of lanthanum, cerium, neodymium and praseodymium. This mix is also called "mischmetal" [8] Catalysts for petroleum cracking and other industrial processes contain lanthanum. Substitutions are rare, and R&D is urgently required for alternative catalysts [8] Hybrid engines, metal alloys [11] Used in expensive camera lenses. Also used in lighter flints, battery electrodes and catalytic converters [13]	Catalysts in petroleum refining and processing might suffer from a lanthanum shortage because no substitutions are available in the short term [8] Probable shortages for energy efficient lamps and displays are to be expected for yttrium and lathanum.There will be shortages in terbium, dysprosium, praseodymium and neodymium at a high degree of probability, even if China imposes no export restrictions [8]. Prices for La metals rose dramatically from 2007-2011 [11] & [8].	Currently no substitutes for lanthanum in FCC catalysts are known, but experts state that there is an additional impetus for reduction or substitution due to the increasing prices of REE like lanthanum [8] There is no current industrial recycling process for the recovery of rare earths from Ni-MH batteries containing La, Ce, Nd and Pr [8] No substitutions available for La in petroleum refining and processing [8] Substitution of Ni-MH batteries (with La and Nd) by Li-ion batteries [8]
For magnets, mainly neodymium and praseodymium (medium price) and dysprosium and terbium (high prices) are used for applications motors, wind turbines and hard disks [8]. Ni-MH batteries are used in hybrid electric vehicles and in portable appliances. Besides nickel and cobalt, they contain a mix of lanthanum, cerium, neodymium and praseodymium. This mix is also called "mischmetal" [8]	Absolute monopoly of China in the production [Expert Judgement]	There is no current industrial recycling process for the recovery of rare earths from Ni-MH batteries containing La, Ce, Nd and Pr [8]. The element praseodymium is seen as less critical though it is widely interchangeable with neodymium [8].
Ni-MH batteries are used in hybrid electric vehicles and in portable appliances. Besides nickel and cobalt, they contain a mix of lanthanum, cerium, neodymium and praseodymium. This mix is also called "mischmetal" [8] For magnets, mainly neodymium and praseodymium (medium price) and dysprosium and terbium (high prices) are used for applications motors, wind turbines and hard disks [8] Highly significant for magnets, laser technology, glas- and porcellain colorcodings [9] Strongest permanent magnet is based on a Nd-Fe-B alloys and are used in wind turbines, electric traction motors for vehicles and miniture components for information and communication technology. also used for micro motors of 1,9mm diameter with a capacity of 60mW; large motors with up to 3m diameter, positioning systems for read and write components in hard disks in computers, magnet systems for MRI products, magnet systems for spektrometers [5]	The production of Ni-MH batteries for hybrid vehicles might become limited due to shortages in neodymium and lanthanum [8] Increasing demand for Neodymium in permanent magnets application; Neodymium demand for magnets 2006: 4.000 tons, predicted demand 2030: 27.900 [14] The highest criticality in terms of supply risk and the importance to clean energy production are the five REE dysprosium, neodymium, terbium, yttrium and europium, which are also seen as critical by Öko-Institut [8] Prices for neodymium metals rose dramatically between 2007 and 2011 [11]	There is no current industrial recycling process for the recovery of rare earths from Ni-MH batteries containing La, Ce, Nd and Pr [8] Substitution of Ni-MH batteries (with La and Nd) by Li-ion batteries [8] High temperature superconductor (HTS) rotors in wind turbines are under research and development. In the superconductor material there is no neodymium; instead yttrium is used [8] There is no adequate substance available to produce a magnet Alloys with similar performance parameters like the Nd-Fe-B. Samarium based matrials are used less because they are less effective in electro motors [5]
Used in magnets [11] Used for doping laser crystals, used in special glasses, ceramics, catalyzer and in neutron absorber in nuclear reactors [15].	China produces 60% of all SmCo magnets worldwide [11]	
Used for red color for television and computer screens [11] Also used for nuclear reactors, highpressure lamps and spectoscopy [17]	Significant shortages for energy efficient lamps and displays are to be expected for europium and terbium [8] The highest criticality in terms of supply risk and the importance to clean energy production are the five REE dysprosium, neodymium, terbium, yttrium and europium, which are also seen as critical by Öko-Institut [8] Prices for (Eu) metals rose dramatically between 2007 and 2011 [11]	Research activities are being undertaken which focus on yttrium and europium recovery from TV tubes and computer monitors [8] OSRAM holds a patent on the recycling of yttrium and europium from discharge lamps and fluorescent lamps [8] There is no proven substitute for europium in fluorescent lamps and no proven substitute for europium as red phosphor in television screens [8]
Used for magnets [11] In magnet optic and neutron radiography [15] Gadoliniumoxide is used in detector in CTs [5]	No risks known because of recycling quota [5]	No risks known because of recycling quota [5].
Ni-MH batteries are used in hybrid electric vehicles and in portable appliances. Besides nickel and cobalt, they contain a mix of lanthanum, cerium, neodymium and praseodymium. This mix is also called "mischmetal" [8] Used for auto catalyst, petroleum refining, hard drives in laptops, headphones, hybrid engines [11] Used for iron and aluminum alloys, used in lighters and for fireworks, in catalysators, UV-filters in glas and windshields, in pottery, dental pottery, contrast agent for MRs, for detergents, and lighting materials [19]		There is no current industrial recycling process for the recovery of rare earths from Ni-MH batteries containing La, Ce, Nd and Pr [8]
Used for lasers and steel alloys [11] used as radiation source in clinical applications [18]		
Used as catalysts in petrolium refining [11] Used in PET scanners and petrolium cracking refinieries [20]	China policy initiatives restrict the exportt of Lu [11] Trades at a high price [20]	Has few substitutes because it is the heaviest and hardest rare earth element [20]
Used for medical x-ray units [11] Used for portable x-ray units [15]	China policy initiatives restrict the export of Tm [11]	
Used for glass coloring, lasers [11] Used for strong magnets [15]		
Used for phosphors [11] Used for nuclear technology, titan alloys and glasses [15]		
For magnets, mainly neodymium and praseodymium (medium price) and dysprosium and terbium (high prices) are used applications motors, wind turbines and hard disks [8] Used for phosphors, permanent magnets [11] Used for fuel cells [17]	Significant shortages for energy efficient lamps and displays are to be expected for europium and terbium. [8] The highest criticality in terms of supply risk and the importance to clean energy production are the five REE dysprosium, neodymium, terbium, yttrium and europium, which are also seen as critical by Öko-Institut [8]	Manganese (Mn^{2+}) as a possible alternative to terbium [8]

	Substance group	Substance details	Periodic table subgroup	Coverage (estimated time of sourcing availability of substance); availability	Political stability of sourcing region other dangers (environment/ health)	3-country concentration (share of three largest sourcing countries of world production of substance)
Metals	Transition metals (Rare Earths)	Lathanoids	Dysprosium (Dy)	Shortages of rare earths for the production of permanent magnets in the short term, with a high degree of probability. The relevant elements are terbium, dysprosium, praseodymium and neodymium [8] There will be likely shortfalls [11] World production less than 100 tons per year [15]		
Metals	Transition metals (Rare Earths)	Actinoids	Thorium (Th)	Thorium resources occur in geologic provinces similar to those that contain reserves. The leading share is contained in placer deposits. Resources of more than 500,000 tons are contained in placer, vein, and carbonatite deposits [1]	Increased costs to monitor and dispose thorium have caused domestic processors to switch to thorium-free materials. Real and potential costs related to compliance with State and Federal regulations, proper disposal, and monitoring of thorium's radioactivity have limited its commercial value. It is likely that thorium's use will continue to decline unless a low-cost disposal process is developed or new technology, such as a nonproliferative nuclear fuel, creates renewed demand [1]	Large thorium resources are found in Australia, Brazil, Canada, Greenland (Denmark), India, South Africa, and the United States [1]
Metals	Transition metals	Wolfram (W) / Tungsten		World tungsten resources are geographically widespread. China ranks first in the world in terms of tungsten resources and reserves and has some of the largest deposits [1]	World tungsten supply is dominated by Chinese production and exports [1]	China, Canada, Kazakhstan, Russia, and the United States [1]
Metals	Transition metals	Cobalt (Co)		Identified world cobalt resources are about 15 million tons. The vast majority of these resources are in nickel-bearing laterite deposits, with most of the rest occurring in nickel-copper sulfide deposits hosted in mafic and ultramafic rocks and in sedimentary copper deposits of Congo (Kinshasa) and Zambia. In addition, as much as 1 billion tons of hypothetical and speculative cobalt resources may exist in manganese nodules and crusts on the ocean floor [1]	Zambia is political not solid and conflict region with DR Congo [2]	Australia, Canada, and Russia, China, France, Japan, Austria; sedimentary copper deposits of Congo Kinshasa) and Zambia [1]
Metals	Transition metals	Molybdenium (Mo)		Molybdenum occurs as the principal metal sulfide in large low-grade porphyry molybdenum deposits and as an associated metal sulfide in low-grade porphyry copper deposits. Resources of molybdenum are adequate to supply world needs for the foreseeable future [1]	Iran with high conflict potential and UN-embargo [2]	USA, China, Chile, Canada, Peru, Mexico, Russia, Armenia, Iran [1]
Metals	Transition metals	Nickel (Ni)		Identified land-based resources averaging 1% nickel or greater contain at least 130 million tons of nickel. About 60% is in laterites and 40% is in sulfide deposits. In addition, extensive deep-sea resources of nickel are in manganese crusts and nodules covering large areas of the ocean floor, particularly in the Pacific Ocean [1]	The longterm decline in discovery of new sulfide deposits in traditional mining districts has forced companies to shift exploration efforts to more challenging locations like the Arabian Peninsula, east-central Africa, and the Subarctic [1]	Canada, Russia, Australia, Norway, USA [1]
Metals	Transition metals	Iron (Fe)	Iron Ore	World resources are estimated to exceed 230 billion tons of iron contained within greater than 800 billion tons of crude ore. [1] World production 1,170 million tons [5]		China, Mexico, Canada, European Union [1]
Metals	Transition metals	Tantalum (Ta)		Identified resources of tantalum, most of which are in Australia and Brazil, are considered adequate to meet projected needs. The United States has about 1,500 tons of tantalum resources in identified deposits, all of which are considered uneconomic at 2010 prices [1]	the sea transportation of material from Mozambique is endangered because of piracy [2]	Australia, Brazil, Canada, Mozambique, Ruanda [1]
Metals	Transition metals	Titanium (Ti)		Resources and reserves of titanium minerals are discussed in Titanium Mineral Concentrates. The commercial feedstock sources for titanium are ilmenite, leucoxene, rutile, slag, and synthetic rutile. Ilmenite accounts for about 91% of the world's consumption of titanium minerals [1]		China, Japan, Kazakstan, Russia, USA [1]
Metals	Transition metals (Precious Metals)	Gold (Au)		51.000 tons of gold reserves located worldwide and a production of 2.500 in 2010 [1]	Highly significant damage categories are human toxicity and aquatic eutrophication [Internal EDIP 2003 study results]	Canada, Mexico, Peru, Chile, USA [1]
Metals	Transition metals (Precious Metals)	Silver (Ag)		510.000 tons of silver reserves located worldwide and a production of 22.000 in 2010 [1]	Highly significant damage categories are human toxicity and aquatic eutrophication [Internal EDIP 2003 study results]	Australia, Mexico, Canada, Peru, Chile, USA [1]

Significance for technologies	Risk of strategic use of substance (trade and competition risks); cost-risk	Substitutability, replaceability
For magnets, mainly neodymium and praseodymium (medium price) and dysprosium and terbium (high prices) are used for applications motors, wind turbines and hard disks [8] Used for permanent magnets, hybrid engines [11]	The highest criticality in terms of supply risk and the importance to clean energy production are the five REE dysprosium, neodymium, terbium, yttrium and europium, which are also seen as critical by Öko-Institut [8] China policy initiatives restrict the exportt of Dy - prices for Dy metals rose dramatically from 2007-2011 [11]	
Catalysts, high-temperature ceramics, and welding electrodes. Thorium's use in most products has generally decreased because of its naturally occurring radioactivity. catalysts, microwave tubes, and optical equipment and was estimated to have increased [1]	Radioactive substance (use and disposal costs at eol) [Expert Judgement]	Nonradioactive substitutes have been developed for many applications of thorium. Yttrium compounds have replaced thorium compounds in incandescent lamp mantles. A magnesium alloy containing lanthanides, yttrium, and zirconium can substitute for magnesium-thorium alloys in aerospace applications [1]
High temperatures superconductor (HTS) rotors are developed with the basic HTS wire substrate nickel tungsten and Yttrium and silver [8]. Highly sighnificant for the lamp industy, metallurgy, military equipment [9] Cemented carbide parts for cutting and wearresistant materials, primarily in the construction, metalworking, mining, and oil- and gas-drilling industries, to make tungsten heavy alloys for applications requiring high- density electrodes, filaments, wires, and other components for electrical, electronic, heating, lighting, and welding applications; steels, superalloys, and wear-resistant alloys; and chemicals [1]	China's Government regulates its tungsten industry by limiting the number of exploration, mining, and export licenses; limiting or forbidding foreign investment; imposing constraints on mining and processing; establishing quotas on production and exports; adjusting export quotas to favor value-added downstream materials and products; and imposing export taxes on tungsten materials. The sole Canadian tungsten mine restarted production in October 2010 after being on care-and-maintenance status for 1 year [1] Reserves-to-production ratio is less than 49 years [21]	Potential substitutes for cemented tungsten carbides include cemented carbides based on molybdenum carbide and titanium carbide, ceramics, ceramic-metallic composites (cermets), diamond tools, and tool steels. Potential substitutes for other applications are as follows: molybdenum for certain tungsten mill products; molybdenum steels for tungsten steels; lighting based on carbon nanotube filaments, induction technology, and lightemitting diodes for lighting based on tungsten electrodes or filaments; depleted uranium for tungsten alloys or unalloyed tungsten in weights and counterweights; and depleted uranium alloys for cemented tungsten carbides or tungsten alloys in armor-piercing projectiles. In some applications, substitution would result in increased cost or a loss in product performance [1]
Highly significant for batteries, superalloys, converters and hard metals [9] Superalloys for mainly aircraft gas turbines engines, cemented carbites for cutting and wear-resistent applications, metallic and chemical applications [1]	China produces 60% of all SmCo magnets worldwide [11]	In some applications, substitution for cobalt would result in a loss in product performance. Potential substitutes include barium or strontium ferrites, neodymium-iron-boron, or nickel-iron alloys in magnets; cerium, iron, lead, manganese, or vanadium in paints; cobalt-iron-copper or iron-copper in diamond tools; iron-cobalt-nickel, nickel, cermets, or ceramics in cutting and wear-resistant materials; iron-phosphorous, manganese, nickel-cobalt-aluminum, or nickel-cobalt-manganese in lithium-ion batteries; nickel-based alloys or ceramics in jet engines; nickel in petroleum catalysts; and rhodium in hydroformylation catalysts [1]
Highly significant for highly alloyed steels, electronics, catalysts, airplane and rocketindustry [9] Ferromolybdenum, metal powder, and various chemicals, Iron and steel and superalloys [1]	Reserves-to-production ratio is less than 45 years [21]	There is little substitution for molybdenum in its major application as an alloying element in steels and cast irons. In fact, because of the availability and versatility of molybdenum, industry has sought to develop new materials that benefit from the alloying properties of the metal. Potential substitutes for molybdenum include chromium, vanadium, niobium (columbium), and boron in alloy steels; tungsten in tool steels; graphite, tungsten, and tantalum for refractory materials in high-temperature electric furnaces; and chrome-orange, cadmium-red, and organic-orange pigments for molybdenum orange [1]
High temperatures superconductor (HTS) rotors are developed with the basic HTS wire substrate nicket tungsten and Yttrium and silver [8] Stainless and alloy steel production, nonferrous alloys and superalloys, electroplating (end uses transportation, chemical industry, household appliances and industrial machinery) [1]	To offset high and fluctuating nickel prices, engineers have been substituting low-nickel, duplex, or ultrahigh-chromium stainless steels for austenitic grades in construction applications [1] Reserves-to-production ratio is less than 51 years [21]	To offset high and fluctuating nickel prices, engineers have been substituting low-nickel, duplex, or ultrahigh-chromium stainless steels for austenitic grades in construction applications. Nickel-free specialty steels are sometimes used in place of stainless steel within the power-generating and petrochemical industries. Titanium alloys can substitute for nickel metal or nickel-based alloys in corrosive chemical environments. Cost savings in manufacturing lithium-ion batteries allow them to compete against nickel-metal hydride in certain applications [1]
	In 2009, China imported almost two-thirds of the world's total iron ore exports and produced about 60% of the world's pig iron. Since international iron ore trade and production of iron ore and pig iron are key indicators of iron ore consumption, this demonstrates that iron ore consumption in China is the primary factor upon which the expansion of the international iron ore industry depends [1] In general, large price increases for lump and fine iron ores and iron ore pellets through mid- 2009 were commensurate with price increases in the alternative—scrap [1]	The only source of primary iron is iron ore, used directly, as lump ore, or converted to briquettes, concentrates, pellets, or sinter. At some blast furnace operations, ferrous scrap may constitute as much as 7% of the blast furnace feedstock. Scrap is extensively used in steelmaking in electric arc furnaces and in iron and steel foundries, but scrap availability can be an issue in any given year [1]
Tantalum capacitors include automotive electronics, pagers, personal computers, and portable telephones [1]		The following materials can be substituted for tantalum, but usually with less effectiveness: niobium in carbides; aluminum and ceramics in electronic capacitors; glass, niobium, platinum, titanium, and zirconium in corrosion-resistant equipment; and hafnium, iridium, molybdenum, niobium, rhenium, and tungsten in high temperature applications [1]
Titanium metal is used in aerospace applications, in chemical industry, power generation, marine, ordnance, medical and other nanoaerospace applications [1]		There are few materials that possess titanium metal's strength-to-weight ratio and corrosion resistance. In high-strength applications, titanium competes with aluminum, composites, intermetallics, steel, and superalloys. Aluminum, nickel, specialty steels, and zirconium alloys may be substituted for titanium for applications that require corrosion resistance. Ground calcium carbonate, precipitated calcium carbonate, kaolin, and talc compete with titanium dioxide as a white pigment [1]
Jewelry manufacturing, electrical and electronics, dental [1]	With the increase in price of gold and the worldwide economic slowdown, investment in gold has increased, as investors seek safe-haven investments [1] Reserves-to-production ratio is about 17 years [15]	Base metals clad with gold alloys are widely used in electrical and electronic products, and in jewelry to economize on gold; many of these products are continually redesigned to maintain high-utility standards with lower gold content. Generally, palladium, platinum, and silver may substitute for gold [1]
High temperatures superconductor (HTS) rotors are developed with the basic HTS wire substrate nicket tungsten and Yttrium and silver [8] Coins and medals, industrial applications, jewelry and silverware, and photography. silver in bandages for wound care, batteries, brazing and soldering, in catalytic converters in automobiles, in cell phone covers to reduce the spread of bacteria, in clothing to minimize odor, electronics and circuit boards, electroplating, hardening bearings, inks, mirrors, solar cells, water purification, and wood treatment to resist mold, miniature antennas, RFIDs [1]	reserves-to-production ratio is about 13 years [15]	Digital imaging, film with reduced silver content, silverless black-and-white film, and xerography substitute for silver that has traditionally been used in black-and-white as well as color printing applications. Surgical pins and plates may be made with tantalum and titanium in place of silver. Stainless steel may be substituted for silver flatware, and germanium added to silver flatware will make it tarnish resistant. Nonsilver batteries may replace silver batteries in some applications. Aluminum and rhodium may be used to replace silver that was traditionally used in mirrors and other reflecting surfaces. Silver may be used to replace more costly metals in catalytic converters for off-road vehicles [1]

	Substance group	Substance details	Periodic table subgroup	Coverage (estimated time of sourcing availability of substance); availability	Political stability of sourcing region other dangers (environment/ health)	3-country concentration (share of three largest sourcing countries of world production of substance)
Metals	Transition metals (Precious Metals)	Copper (Cu)		A preliminary assessment indicates that global land-based resources exceed 3 billion tons. Deep-sea nodules and massive sulfides are potential copper resources [1] Copper represents the 26th most common element within the earth crust as CuFeS2 and Cu2S as well as Cu2O [5] Recycling of copper is an essential part of the copper production. It contributes approximately 36% of the world used copper [22]	Further references on this distribution can be found in [22] The largest resources of copper with 30% of the world share are in Chile. More unknown reserves are expected to be found in Republic of the Congo and DR Congo [5] Lagest copper production (36%) ist in Chile, then 7,7% in Peru and 7,6% in USA. Argentina has doubled its production since 1995, and Peru, Indonesia and Kasachztan have also significantly expanded their production scope [5] Highly significant damage categories are human toxicity and aquatic eutrophication [Internal EDIP 2003 study results]	Chile, Canada, Peru, Mexico, USA [1]
Metals	Transition metals (Precious Metals)	Platinum (Pt)	primary platinum-group metals (PGMs)	World resources of PGMs in mineral concentrations that can be mined economically are estimated to total more than 100 million kilograms [1] Worldproduction 2007: 230 tons, reserves of platinmetals are about 100.000 tons [5]	The largest reserves are in the Bushveld Complex in South Africa [1] World production dominated by South Africa [5]	South Africa, Germany, United Kingdom, Canada, USA, Belgium, Russia [1]
Metals	Transition metals (Precious Metals)	Palladium (Pd)		Worldproduction 2007: 232 tons, reserves of platinmetals are about 100.000 tons [5]	Worldproduction dominated by South Africa [5] Zimbabwe is politically insecure [2]	Russia, South Africa, Canada, USA, Zimbabwe [5]
Metals	Transition metals	Chromium (Cr)/ Chromite ore		World resources are greater than 12 billion tons of shipping-grade chromite, sufficient to meet conceivable demand for centuries [1] World production in 2006: 19.6 million tons [5]	About 95% of the world's chromium resources is geographically concentrated in Kazakhstan and southern Africa; U.S. chromium resources are mostly in the Stillwater Complex in Montana [1] Highly significant damage cause in radioactive waste [Internal EDIP 2003 study results]	Kazakhstan, South Africa [5]
Metals	Transition metals	Vanadium (V)		Vanadium is usually recovered as a by-product or co-product, demonstrated world resources of the element are not fully indicative of available supplies. While domestic resources and secondary recovery are adequate to supply a large portion of domestic needs; worldwide reserves about 13 million tons [1] World production 2006: 62.400 tons [5]		Rep. of Korea, Czech Republic, Canada, Austria, USA; China, Russia, South Africa [1]
Metals	Transition metals	Rhenium (Re)		World reserves of Rhenium about 2.500 tons, world production about 48 tons in 2010 [5]	Owing to the scarcity and minor output of rhenium, its production and processing pose no known threat to the environment. In areas where it is recovered, pollution-control equipment for sulfur dioxide removal also prevents most of the rhenium from escaping into the atmosphere [1]	Kazakhstan, Chile, Netherlands, USA [1]
Metals	Transition metals	Niobium (Nb)		World resources are more than adequate to supply projected needs. Most of the world's identified resources of niobium occur mainly as pyrochlore in carbonatite; worldwide mine production 2010: 63,000 tons [1] World reserves about 2.7 million tons [5]	Over 90 % of the Nioboxide is produced in Brazil [5]	Brazil, Canada, Germany, Estonia [1]
Metals	Transition metals	Manganese (Mn)		Land-based manganese resources are large but irregularly distributed; World reserves about 630 million tons [1] World production 2006: 11.9 million tons [5]	South Africa accounts for about 75% of the world's identified manganese resources, and Ukraine accounts for 10% [1] Significant damage caused in radioactive waste [Internal EDIP 2003 study results]	Ukraine, South Africa, Gabon, China, Australia, Mexico, Australia, Brazil [1]
Metals	Poor metals	Aluminium (Al)		The world reserves for bauxite are sufficient to meet world demand for metal well into the future [1]	Significant damage caused in radioactive waste [Internal EDIP 2003 study results]	USA, China, United Arab Emirates, Russia, India, Canada, Brazil, Australia etc. [1]
Metals	Poor metals	Bismuth (Bi)		Bismuth, at an estimated 8 parts per billion by weight, is the 69th element in order of abundance in the Earth's crust and is about twice as abundant as gold. World reserves of bismuth are usually based on bismuth content of lead resources because bismuth production is most often a byproduct of processing lead ores; in China, bismuth production is a byproduct of tungsten and other metal ore processing. Bismuth minerals rarely occur in sufficient quantities to be mined as principal products; the Tasna Mine in Bolivia and a mine in China are the only mines that produced bismuth from a bismuth ore. Several bismuth-containing deposits are in varying stages of mining feasibility review. These polymetallic deposits include Bonfim in Brazil, NICO in Canada, and Nui Phao in Vietnam. Worldwide mine production 2010: 7600 tons; world reserves about 320,000 tons [1]	Bismuth, on the other hand, is an environmentally friendly substitute for lead in plumbing and many other applications, including fishing weights, hunting ammunition, lubricating greases, and soldering alloys [1]	Belgium, China, United Kingdom, Mexico [1]

Significance for technologies	**Risk of strategic use of substance (trade and competition risks); cost-risk**	**Substitutability, replaceability**
Used in antimicrobial touch surfaces, lead-free brass plumbing, high tech wire, heat exchangers, coins, computers, electrical appliances, cookware, brassware, locks & keys, in power cables for low, medium & high voltage applications. Preferrend because of its characterstics in strength, ductility, resistance to creeping & corrosion for safest conductor for building wiring. Essential component of energy efficient generators, motors, transformers and renewable energy production systems (e.g. solar, wind, geothermal, fuel cells) because of excellent conductivity. Project to facilitate the transfer of technology related to the manufacture of rotors, motors and motor systems using more energy efficient high pressure copper die castings. Used in information & com. technologies (HDSL & ADSL) for high speed data transmission in domestic subscriber lines, wide and local area networks, mobile phones and PCs, and copper chips using a copper circuity in silicon chips, in wires, transformers, connectors & switches. Copper nickel alloy is used for boat hulls and ships, automobiles & trucks (wiring, radiators, connectors, brakes & bearings). Electric & hybrid vehicles contain high levels of copper. Used in auto radiators because of superior thermal conductivity, strength, corrosion resistance & recyclability, resulting in lighter, smaller and more efficient radiators. Used extensively in new airplanes & trains (e.g. high-speed trains can use from 2 to 4 tonnes of copper and 1-2 tonnes used in trad. elec. trains). Industrial machinery and equip. need copper and its alloys to support durability, machinability & cast with high precision, copper alloys ideal for making gears, bearings & turbine blades. Vessels, tanks & piping exposed to seawater, propellers, oil platforms and coastal power stations, all depend on copper's corrosion resistance for protection. Copper & Brass are main materials used for plumbing, taps, valves & fittings, faces, roofing, doors & window frames. Used in fire sprinklers & to protect from bacteria in water (e.g. legionella). Biostatic properties help to prevent the transfer of disease & microbes [22] Most common pure copper use in cables & brass alloys [5] Building construction, electric & electronic products, transportation equipment; consumer & general products, industrial machinery & equipment [1]	Copper prices are determined by raw material stock exchanges. The price for copper has increase significantly by 150% within the last 10 years, since 2001, mostly due to the increase in demand by China [5] China is by far the major user of copper, second it western Europe and third North America, Fourth Japan [22]	Aluminum substitutes for copper in power cables, electrical equipment, automobile radiators, and cooling and refrigeration tube; titanium and steel are used in heat exchangers; optical fiber substitutes for copper in telecommunications applications; and plastics substitute for copper in water pipe, drain pipe, and plumbing fixtures [1]
There is research on fuel cells for electric vehicles which could operate without the expensive platinum or palladium catalysts [8] Highly significant for catalysts, jewelery industry, electronics, chemicals, dental technology [9] Used in the chemical sector as catalysts for manufacturing bulk chemicals (e.g. nitric acid) & in the production of specialty silicones; in the petroleum refining sector; in the fabrication of laboratory equipment; in the electronics sector. PGMs are used in computer hard disks, multilayer ceramic capacitors & hybridized integrated circuits. PGMs are used by the glass manufacturing sector in the production of fiberglass, liquid crystal displays, and flat-panel displays. Platinum alloys, in cast or wrought form, are commonly used for jewelry. Platinum, palladium, and a variety of complex gold-silvercopper alloys are used as dental restorative materials [1]	Reserves-to-production ratio is about 190 years; massiv cost raising in last years, fuel cells need platin [5]	Many motor vehicle manufacturers have substituted palladium for the more expensive platinum in gasoline-engine catalytic converters. Until recently, only platinum could be used in diesel catalytic converters; however, new technologies allow as much as 25% palladium to be used, and laboratory experiments have increased that proportion to around 50%. For other end uses, PGMs can be substituted for other PGMs, with some losses in efficiency [1]
There is research on fuel cells for electric vehicles which could operate without the expensive platinum or palladium catalysts [8]	Reserves-to-production ratio is about 190 years [5]	
Highly significant for highly alloyed steels, fire resistant industry, chemicals, colours [9] Chomium chemicals, stainless and heat-resisting-steel producers, superalloys [1]	Reserves-to-production ratio is only about 25 years [21] Resource range is about 600 years [5]	Chromium has no substitute in stainless steel, the leading end use, or in superalloys, the major strategic end use. Chromium-containing scrap can substitute for ferrochromium in some metallurgical uses [1]
Alloying agent for iron and steel, ferrovanadium, vanadium pentoxide, vanadium metal, and vanadium-bearing chemicals or specialty alloys [1]	The forcast for 2030 req. about 74.000 tons [5]	Steels containing various combinations of other alloying elements can be substituted for steels containing vanadium. Certain metals, such as manganese, molybdenum, niobium (columbium), titanium, and tungsten, are to some degree interchangeable with vanadium as alloying elements in steel. Platinum and nickel can replace vanadium compounds as catalysts in some chemical processes. There is currently no acceptable substitute for vanadium in aerospace titanium alloys [1]
Uses of rhenium were in petroleum-reforming catalysts and in superalloys used in high-temperature turbine engine components; used in petroleum-reforming for the production of high-octane hydrocarbons, which are used in the production of lead-free gasoline; used in crucibles, electrical contacts, electromagnets, electron tubes and targets, heating elements, ionization gauges, mass spectrographs, metallic coatings, semiconductors, temperature controls, thermocouples, vacuum tubes [1] Tumour therapy [17]		Substitutes for rhenium in platinum-rhenium catalysts are being evaluated continually. Iridium and tin have achieved commercial success in one such application. Other metals being evaluated for catalytic use include gallium, germanium, indium, selenium, silicon, tungsten, and vanadium. The use of these and other metals in bimetallic catalysts might decrease rhenium's share of the existing catalyst market; however, this would likely be offset by rhenium-bearing catalysts being considered for use in several proposed gas-to-liquid projects. Materials that can substitute for rhenium in various end uses are as follows: cobalt and tungsten for coatings on copper x-ray targets, rhodium and rhodium-iridium for high-temperature thermocouples, tungsten and platinum-ruthenium for coatings on electrical contacts, and tungsten and tantalum for electron emitters [1]
Highly significant for the stell industry (supra alloys, highly alloyed steels), electronics, turbines [9] Consumed mostly in the form of ferroniobium by the steel industry and as niobium alloys and metal by the aerospace industry; steels, superalloys [1]	China manufactures 75% of all NeFeB magnets [11] The leading suppliers of niobium in ore and concentrate were Mozambique and Canada [1] Reserves-to-production ratio is only about 47 years [21] Resource range about 10.000 years [5]	The following materials can be substituted for niobium, but a performance or cost penalty may ensue: molybdenum and vanadium, as alloying elements in high-strength low-alloy steels; tantalum and titanium, as alloying elements in stainless and high-strength steels; and ceramics, molybdenum, tantalum, and tungsten in hightemperature applications [1]
Used for such non-metallurgical purposes as production of dry cell batteries, in plant fertilizers and animal feed, and as a brick colorant. Manganese ferroalloys were produced at two smelters. Construction, machinery, and transportation; a variety of other iron and steel applications [1]	Land-based manganese resources are large but irregularly distributed; those of the United States are very low grade and have potentially high extraction costs [1] Reserves-to-production ratio is only about 44 years, recource range is about 531 years [15]	no satisfactory substitute for Manganese [1]
Aluminium is used for packaging, transportation, building, electrical, machinery and consumer durables [1]	World primary aluminum production increased in 2010 compared with production in 2009, mainly as a result of starting new smelters and restarting smelters that had been shut down in 2008 and early in 2009. New smelters and restarted smelters were mainly in China, Qatar, and the United Arab Emirates. Smelters in Norway that shut down production during midyear 2009 remained closed in 2010 [1]	Composites can substitute for aluminum in aircraft fuselages and wings. Glass, paper, plastics, and steel can substitute for aluminum in packaging. Magnesium, titanium, and steel can substitute for aluminum in ground transportation and structural uses. Composites, steel, vinyl, and wood can substitute for aluminum in construction. Copper can replace aluminum in electrical applications [1]
Bismuth as a metallurgical additive to lead-free pipes; use of zinc-bismuth alloys to achieve thinner and more uniform galvanization; in the manufacture of ceramic glazes, crystal ware, and pigments; as an additive to free-machining steels; and as an additive to malleable iron castings. Currently, researchers in the European Union, Japan, and the United States are investigating the possibilities of using bismuth in lead-free solders. Researchers are examining liquid lead-bismuth coolants for use in nuclear reactors. Work is proceeding toward developing a bismuth-containing metal-polymer bullet [1]	The Tasna Mine had been on standby status since the mid-1990s awaiting a significant and sustained rise in the metal price, and in late 2008 there were reports that it had reopened [1]	Bismuth can be replaced in pharmaceutical applications by alumina, antibiotics, and magnesia. Titanium dioxide-coated mica flakes and fish scale extracts are substitutes in pigment uses. Indium can replace bismuth in owtemperature solders. Resins can replace bismuth alloys for holding metal shapes during machining, and glycerinefilled glass bulbs can replace bismuth alloys in triggering devices for fire sprinklers. Free-machining alloys can contain lead, selenium, or tellurium as a replacement for bismuth. Bismuth, on the other hand, is an environmentally friendly substitute for lead in plumbing and many other applications, including fishing weights, hunting ammunition, lubricating greases, and soldering alloys [1]

	Substance group	Substance details	Periodic table subgroup	Coverage (estimated time of sourcing availability of substance); availability	Political stability of sourcing region other dangers (environment/ health)	3-country concentration (share of three largest sourcing countries of world production of substance)
Metals	Poor metals	Gallium (Ga)		World production of rafineried Gallium 2007: 103 tons, estimated resources about 1 million tons [5]		Germany, Canada, China, Ukraine [1]
Metals	Poor metals	Lead (Pb)		Significant lead resources have been demonstrated in association with zinc and/or silver or copper deposits in Australia, China, Ireland, Mexico, Peru, Portugal, Russia, and the United States (Alaska) [1]	China was expected to account for more than 40% of global lead mine production. Global refined lead production was expected to increase by about 5% from that in 2009 [1] Significant damage caused in human toxicity water and aquatic eutrophication [Internal EDIP 2003 study results]	
Metals	Poor metals	Mercury (Hg)		Resources are sufficient for another century or more of use [1]	Mercury toxicity and concerns for human health [1] Highly significant damage caused in human toxicity water, soil and air [Internal EDIP 2003 study results] Kyrgyzstan is after inner conflicts 2010 approximated solid Democratic Republic of the Congo [2]	China, Kyrgyzstan, Russia, Slovenia, Spain, and Ukraine [1]
Metals	Poor metals	Tin (Sn) / Stannum		World resources are sufficient to sustain recent annual production rates well into the future [1]	World resources, principally in western Africa, southeastern Asia, Australia, Bolivia, Brazil, China, and Russia [1] Appearance of recurrent disturbances in Bolivia; Indonesia after inner conflicts currently solid [2]	Peru, Bolivia, China, Indonesia, USA [1]
Metals	Poor metals	Zinc (Zn)		Worldwide mine production 2010: 12,000 tons. World reserves 250,000 tons . Identified zinc resources of the world are about 1.9 billion metric tons [1]	Significant damage caused in human toxicity water, soil and aquatic eutrophication [Internal EDIP 2003 study results]	Canada, Peru, Mexico, Ireland, USA [1]
Metals	Poor metals	Antimony (Sb)		Worldwide mine production 2010: 135,000 tons, worldwide reserves about 1.8 million tons [1]	New mining projects in Australia, Canada and Laos; Principal identified world resources are in Bolivia, China, Mexico, Russia, and South Africa. Additional antimony resources may occur in Mississippi Valley-type lead deposits in the Eastern United States. [1] Significant damage caused in human toxicity air, water, soil and aquatic eutrophication [Internal EDIP 2003 study results]	China, Bolivia, Mexico, Peru, Belgium [1]
Metals	Poor metals	Germanium (Ge)		EU has identified germanium as 1 of 14 raw materials on a list of critical supply concerns for its member countries based on each material's level of production, substitutability, and recycling rate & risks associated with the location of supply sources. The available resources of germanium are associated with certain zinc and lead-zinc copper sulfide ores. Significant amounts of germanium are contained in ash and flue dust generated in the combustion of certain coals for power generation. Reserves exclude germanium contained in coal ash [1] Worldwide refinery production 2010: 120 tons [1]	China produces over 60% Germanium [1]	China, Russia, USA [1]
Metals	Poor metals	Polonium (Po)		No industrial relevance [Internal Expert Judgement]		
Metals	Poor metals	Thallium (Tl)		Thallium world production will not be able to meet the demands for HTS and TBCCO, this significant demand effects are expected. World production 2006: 10 tons [5]	Under its national primary drinking water regulations, the EPA has set an enforceable Maximum Contaminant Level for thallium at 2 parts per billion. All public water supplies must abide by these regulations. The EPA continued to conduct studies at its National Risk Management Research Laboratory (NRMRL) to develop & promote technologies that protect & improve human health and the environment. Studies were conducted recently at NRMRL on methods to remove thallium from mine waste waters [1]	Thallium metal and its compounds are highly toxic materials and are strictly controlled to prevent a threat to humans and the environment. Thallium and its compounds can be absorbed into the human body by skin contact, ingestion, or inhalation of dust or fumes. Further information on thallium toxicity can be found in the U.S. Environmental Protection Agency (EPA) Integrated Risk Information System database. Russia, Germany, Netherlands [1]
Metals	Poor metals	Indium (In)		Indium's abundance in the continental crust is estimated to be approximately 0.05 part per million. Trace amounts of indium occur in base metal sulfides—particularly chalcopyrite, sphalerite, and stannite—by ionic substitution. Indium is most commonly recovered from the zinc-sulfide ore mineral sphalerite. The average indium content of zinc deposits from which it is recovered ranges from less than 1 part per million to 100 parts per million. Although the geochemical properties of indium are such that it occurs with other base metals—copper, lead, and tin— and to a lesser extent with bismuth, cadmium, and silver, most deposits of these metals are subeconomic for indium. Quantitative estimates of reserves are not available [1] World production 2006: 510 tons [5]		China, Canada, Japan, Belgium [1]

Significance for technologies	Risk of strategic use of substance (trade and competition risks); cost-risk	Substitutability, replaceability
Optoelectronic devices, which include laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells, represented 35% of gallium demand. The remaining 1% was used in research and development, specialty alloys, and other applications. Optoelectronic devices were used in areas such as aerospace, consumer goods, industrial equipment, medical equipment, and telecommunications. ICs were used in defense applications, high-performance computers, and telecommunications. ower electronics, grid-scale energy storage, and building efficiency. copper-indium-gallium diselenide (CIGS) thin-film solar cell. The company's CIGS material features a flexible substrate that allows it to be lightweight, flexible, and durable, unlike traditional solar panels that tend to be heavy, rigid, and fragile. The Fraunhofer Institute for Solar Energy Systems in Freiburg, Germany, confirmed the new results [1]	Resource range about 10.000 years [5]	Liquid crystals made from organic compounds are used in visual displays as substitutes for LEDs. Researchers also are working to develop organic-based LEDs that may compete with GaAs in the future. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and GaAs competes with helium-neon lasers in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. GaAs-based ICs are used in many defense-related applications because of their unique properties, and there are no effective substitutes for GaAs in these applications. GaAs in heterojunction bipolar transistors is being challenged in some applications by silicon-germanium [1]
Lead-acid batteries for uninterrupticle power supply [1] Lead shielding and lead counterweight for CT and PET or other x-ray applications. Used for superconducting connections for MRI magnets and in x-ray tube bearings, x-ray measurement and photon counting [25]	Reserves-to-production ratio is only about 20 years [21]	Substitution of plastics has reduced the use of lead in cable covering, cans, and containers. Aluminum, iron, plastics, and tin compete with lead in other packaging and coatings. Tin has replaced lead in solder for new or replacement potable water systems. In the electronics industry, there has been a move towards lead-free solders with compositions of bismuth, copper, silver, and tin. Steel and zinc were common substitutes for lead in wheel weights [1]
Batteries, compact and traditional fluorescent lamps, dental amalgam, medical devices, and thermostats, as well as mercury-contaminated soils; chlorine-caustic soda production, compact and traditional fluorescent lights, dental amalgam, neon lights, and small-scale gold mining; fireworks, folk medicines, grandfather clocks, pesticides, and some skin-lightening creams and soaps [1]	The additional projected demand for HBCCO will trigger a significant demand effect for mercury [5] China, Kyrgyzstan, Russia, Slovenia, Spain, and Ukraine have most of the world's estimated 600,000 tons of mercury resources [1]	For aesthetic or human health concerns, natural-appearing ceramic composites substitute for the darkgray mercury-containing dental amalgam. "Galistan," an alloy of gallium, indium, and tin, or alternatively, digital thermometers, now replaces the mercury used in traditional mercury thermometers. Mercury-cell technology is being replaced by newer diaphragm and membrane cell technology at chlor-alkali plants. Light-emitting diodes that ontain indium substitute for mercury-containing fluorescent lamps. Lithium, nickel-cadmium, and zinc-air batteries replace mercury-zinc batteries in the United States, indium compounds substitute for mercury in alkaline batteries, and organic compounds have been substituted for mercury fungicides in latex paint [1]
Electrical, cans and containers, construction, transportation; major tin-consuming countries to move to new lead-free solders that usually contain greater amounts of tin than do leaded solders [1]	China continued as the world's leading tin producer from both mine and smelter sources but experienced sporadic difficulty in obtaining feedstock for its smelters. Indonesia, the world's second leading tin producer from both mine and smelter sources, continued to experience production difficulties, some related to a Government shutdown of possibly illegal production sites [1] Reserves-to-production ratio is about 18 years [21]	Aluminum, glass, paper, plastic, or tin-free steel substitute for tin in cans and containers. Other materials that substitute for tin are epoxy resins for solder; aluminum alloys, copper-base alloys, and plastics for bronze; plastics for bearing metals that contain tin; and compounds of lead and sodium for some tin chemicals [1]
Galvanizing, zinc-based alloys, brass and bronze; Zinc compounds and dust were used principally by the agriculture, chemical, paint, and rubber industries [1]	reserves-to-production ratio is only about 18 years [21]	Aluminum, plastics, and steel substitute for galvanized sheet. Aluminum, magnesium, and plastics are major competitors as diecasting materials. Aluminum alloy, cadmium, paint, and plastic coatings replace zinc for corrosion protection; aluminum alloys substitute for brass. Many elements are substitutes for zinc in chemical, electronic, and pigment uses [1]
Flame retardants, transportation, including batteries, chemicals, ceramics and glass [1]	China, the world's leading antimony producer; strong price increase in 2010 and 2011 due to production interruptions in China (illegal mines and curbing production prevention actions taken) [1] Reserves-to-production ratio is only about 11 years [21]	Compounds of chromium, tin, titanium, zinc, and zirconium substitute for antimony chemicals in paint, pigments, and enamels. Combinations of cadmium, calcium, copper, selenium, strontium, sulfur, and tin can be used as substitutes for hardening lead. Selected organic compounds and hydrated aluminum oxide are widely accepted substitutes as flame retardants [1]
Highly significant for glas fibres, semi-conductors, optic infrared, polymer-katalysts [9] Fiber-optic systems, infrared optics, polymerization catalysts, electronics and solar electric applications, phosphors, metallurgy, and chemotherapy. Consumption of germanium dioxide for use in catalysts for polyethylene terephthalate (PET) production, new type of phase-change memory chip, using an alloy of antimony, germanium, and titanium that could extend battery life in mobile devices by as much as 20% [1] High-frequency technology, night vision device [17]		Silicon can be a less-expensive substitute for germanium in certain electronic applications. Some metallic compounds can be substituted in high-frequency electronics applications and in some light-emitting-diode applications. Zinc selenide and germanium glass substitute for germanium metal in infrared applications systems but often at the expense of performance. Titanium has the potential to be a substitute as a polymerization catalyst [1]
	Radioactive substance (use and disposal costs at eol) [Expert Judgement]	
Thallium as an activator (sodium iodide crystal doped with thallium) in gamma radiation detection equipment (scintillometer); thallium-barium-calcium-copper oxide high-temperature superconductor (HTS) used in filters for wireless communications; thallium in lenses, prisms and windows for infrared detection and transmission equipment; thallium-arsenic-selenium crystal filters for light diffraction in acousto-optical measuring devices; and thallium as an alloying component with mercury for low-temperature measurements. Other uses included an additive in glass to increase its refractive index and density, a catalyst for organic compound synthesis, and a component in high-density liquids for sink-float separation of minerals. Technetium-99 has a very short half-life so it needs to be produced on a continual basis and cannot be stockpiled. Following the closure of these two plants, medical care facilities had a difficult time acquiring adequate supplies of technetium-99 and were forced to cancel scans or use alternative types of tests. The thallium isotope 201 was the most common alternative to technetium-99 for use in scans, such as the cardiac-stress test that monitors blood perfusion into heart tissue during vigorous exercise [1]		The apparent leading potential demand for thallium could be in the area of HTS materials, but demand will be based on which HTS formulation has a combination of favorable electrical and physical qualities and is best suited for fabrication. A firm presently using a thallium HTS material in filters for wireless communications is considering using a nonthallium HTS. While research in HTS continues, and thallium is part of that research effort, it is not guaranteed that HTS products will be a large user of thallium in the future. Although other materials and formulations can substitute for thallium in gamma radiation detection equipment and optics used for infrared detection and transmission, thallium materials are presently superior and more cost effective for these very specialized uses. Nonpoisonous substitutes like tungsten compounds are being marketed as substitutes for thallium in high-density liquids for sink-float separation of minerals [1]
Highly significant for displays and thin-layered photovoltaic products [9] Indium tin oxide (ITO) continued to be the leading end use of indium and accounted for most global indium consumption. ITO thin-film coatings were primarily used for electrically conductive purposes in a variety of flat-panel devices—most commonly liquid crystal displays (LCDs). Other end uses included solders and alloys, compounds, electrical components and semiconductors, and research [1]	Indium's recent price volatility and various supply concerns associated with the metal have accelerated the development of ITO substitutes [1] Indium consumption in Japan (the leading global consumer of indium) was expected to increase by 20% in 2010 from that of 2009. Additionally, Chinese indium consumption was expected to continue to increase significantly, rising by 56% from that of 2009 to 75 tons owing to increased domestic demand for LCD-containing electronics [1] Reserves-to-production ratio is only about 6 years [15]	Antimony tin oxide coatings, which are deposited by an ink-jetting process, have been developed as an alternative to ITO coatings in LCDs and have been successfully annealed to LCD glass. Carbon nanotube coatings, applied by wet-processing techniques, have been developed as an alternative to ITO coatings in flexible displays, solar cells, and touch screens. Poly(3,4-ethylene dioxythiophene) (PEDOT) has also been developed as a substitute for ITO in flexible displays and organic light-emitting diodes. PEDOT can be applied in a variety of ways, including spin coating, dip coating, and printing techniques. Graphene quantum dots have been developed to replace ITO electrodes in solar cells and also have been explored as a replacement for ITO in LCDs. Researchers have recently developed a more adhesive zinc oxide nanopowder to replace ITO in LCDs. The technology was estimated to be commercially available within the next 3 years. Gallium arsenide can substitute for indium phosphide in solar cells and in many semiconductor applications. Hafnium can replace indium in nuclear reactor control rod alloys [1]

	Substance group	Substance details	Periodic table subgroup	Coverage (estimated time of sourcing availability of substance); availability	Political stability of sourcing region other dangers (environment/ health)	3-country concentration (share of three largest sourcing countries of world production of substance)
Nonmetals	Other non metals	Tellurium (Te)		The figures shown for reserves include tellurium contained in economic copper deposits. These estimates assume that less than 1/2 of the tellurium contained in unrefined copper anodes is actually recovered. With increased concern for supply of tellurium, companies are investigating other potential sources, such as gold telluride and lead-zinc ores with higher concentrations of tellurium, which are not included in estimated world resources. More than 90% of tellurium is produced from anode slimes collected from electrolytic copper refining, and the remainder is derived from skimmings at lead refineries and from flue dusts and gases generated during the smelting of bismuth, copper, and lead ores. In copper production, tellurium is recovered only from the electrolytic refining of smelted copper. Increasing use of the leaching solvent extraction-electrowinning processes for copper extraction, which does not capture tellurium, has limited the future supply of tellurium supply from certain copper deposit types [1] Very rare element, Tellurium mainly extracted from copper anode sludge [18]		Japan, Russia, Peru, Canada [1]
Nonmetals	Other non metals	Phosphorous (P)		Phosphate rock world production in 2010: 176.000 tons, reserves about 65 million tons [1]		China, USA, Morocco and Western Sahara [1]
Nonmetals	Other non metals	Sulfur (S)		The worldwide amount of elemental sulfur resources in evaporite and volcanic deposits and other sources are about 5 billion tons [1]	Large resource deposits worldwide [Internal Expert Judgement]	USA, China, Russia, Canada, Deutschland, Japan, Saudi Arabia [1]
Nonmetals	Other non metals	Selenium (Se)		Selenium mainly extracted as byproduct in copper electrolytic refining, the world production 2010: 2.260 tons and the reserves are about 88.000 tons. Co-production with other metals like copper [1]		Japan, Germany, Belgium, Canada, Russia [1]
Nonmetals	Other non metals	Arsenic (As)		Worldwide production 2006: 59.200 tons, world reserves are estimated over 1 million tons [1]	Arsenic has a high human toxically and is hazardous to the environment, in some regions a harmful concentration of arsenic is found in the drinking water [6]	China, Chile, Morocco, Peru [1]
Nonmetals	Other non metals	Boron (B)		Boron does not exist by itself in nature, it is containing in Borate minerals, the world reserves are about 172 million tons, world production is about 4,346 million tons [23]		Boron minerals stem mostly from Turkey, USA, Russia [18]
Nonmetals	Other non metals	Silicon (Si)		25,8% of the lithosphere is Silicon and is part of Quartz (SiO2) [23]	No known dangers [1]	China, Russia, Venezuela, Canada, USA [1]
Nonmetals	Other non metals	Nitrogen (N)		The 78% of the atmosphere consists of Nitrogen and is often synthesized to Ammonia [18] the Ammonia production was about 131 million in 2010 [1]	No known dangers [1]	Ammonia production: China, India, Russia, USA and Trinidad and Tobago [1]
Halogen		Fluorine (F)		Florine is pounded in Fluorspar (CaF2) [23] Fluorspar world production 2010: 5.4 million tons, Fluorspar world reserves about 230 billion tons [1]		Fluorspar producers: China, Mexico, Mongolia [1]
Halogen		Chlorine (Cl)		Chlorine is common on earth and it is mainly bounded in salts [18]	Chlorine has a high human toxically and is hazardous to the environment [6]	
Halogen		Bromine (Br)		Bromine worldproduction 2010: 380000 tons, large estimated world reserves about 100 trilion tons [1]	Jordan is in a conflict region [2] Bromine has a high human toxically and is hazardous to the environment [6]	USA, China, Israel, Jordan [1]
Halogen		Iodine (I)		Iodine worldproduction 2010: 29000 tons. World reserves about 15 million tons [1]	Chile produces more than 50% of the Iodine world production [1]	Chile, Japan, USA [1]
Halogen		Astatine (At)		Astatine is extremly rare element on earth, it is synthetic produced out of Bismut [18]		
Noble gas		Helium (He)		Worldwide Helium recources were estimated to be about 31.1 billion m^3, the world production 2010 is about 150 million m^3 [1]	Algeria with potential risk of conflicts [2]	Qatar (10.1 billion m^3), Algeria (8.2), Russia (6.8), Canada (2.0), China (1.1) [1]
Noble gas		Neon (Ne)		Neon is a very rare element on earth, Neon is a byproduct at the fractionated distillation of liquefied air [18]		
Noble gas		Argon (Ar)		Argon is a rare element on earth, but it is the most common noble gas in atmosphere, Argon is a byproduct at the fractionated distillation of liquefied air [18]		
Noble gas		Krypton (Kr)		Krypton is a very rare element on earth, Krypton is a byproduct at the fractionated distillation of liquefied air [18]		
Noble gas		Xenon (Xe)		Xenon is a very rare element on earth, Xenon is a byproduct at the fractionated distillation of liquefied air [18]		
Noble gas		Radon (Rn)		Radon is extremly rare element on earth [18]		Worldwide no significant sourcing [18]

Significance for technologies	Risk of strategic use of substance (trade and competition risks); cost-risk	Substitutability, replaceability
Major use is as an alloying additive in steel to improve machining characteristics; in copper alloys to improve machinability without reducing conductivity; in lead alloys to improve resistance to vibration and fatigue; in cast iron to help control the depth of chill; and in malleable iron as a carbide stabilizer. It is used in the chemical industry as a vulcanizing agent and accelerator in the processing of rubber, and as a component of catalysts for synthetic fiber production. Tellurium was increasingly used in the production of cadmium-tellurium-based solar cells. Production of bismuth-telluride thermoelectric cooling devices decreased owing to the reduced manufacturing of automobiles containing seat-cooling systems. Other uses include those in photoreceptor and thermoelectric electronic devices, other thermal cooling devices, as an ingredient in blasting caps, and as a pigment to produce various colors in glass and ceramics. Tellurium is used in steel alloys, rupper production, in solar cells, photoreceptors and thermoelectric electronic devices [1]	world recources about 100.000 tons [5]	Several materials can replace tellurium in most of its uses, but usually with losses in production efficiency or product characteristics. Bismuth, calcium, lead, phosphorus, selenium, and sulfur can be used in place of tellurium in many free-machining steels. Several of the chemical process reactions catalyzed by tellurium can be carried out with other catalysts or by means of noncatalyzed processes. In rubber compounding, sulfur and/or selenium can act as vulcanization agents in place of tellurium. The selenides of the refractory metals can function as high-temperature, high-vacuum lubricants in place of tellurides. The selenides and sulfides of niobium and tantalum can serve as electrically conducting solid lubricants in place of tellurides of those metals. The selenium-tellurium photoreceptors used in some xerographic copiers and laser printers have been replaced by organic photoreceptors in newer machines. Amorphous silicon and copper indium diselenide are the two principal competitors to cadmium telluride in photovoltaic power cells [1]
Sulfur consumed was provided by imported sulfur and sulfuric acid; consumed was in the form of sulfuric acid. Agricultural chemicals (primarily fertilizers) composed about 60% of identified sulfur demand; petroleum refining, 24%; and metal mining, 4% [1]		Substitutes for sulfur are not satisfactory present [1]
Highly significant for the chemicals and pigments industry, electronics, metallurgy [9] Solar cells [17]	Reserves-to-production ratio is about 53 years [5]	
Ammunition used by the United States military was hardened by the addition of less than 1% arsenic metal, and the grids in lead-acid storage batteries were strengthened by the addition of arsenic metal. Arsenic metal was also used as an antifriction additive for bearings, in lead shot, and in clip-on wheel weights. Arsenic compounds were used in fertilizers, fireworks, herbicides, and insecticides. High-purity arsenic (99.9999%) was used by the electronics industry for gallium-arsenide semiconductors that are used for solar cells, space research, and telecommunication. Arsenic was also used for germanium-arsenide-selenide specialty optical materials. Indium gallium arsenide was used for short-wave infrared technology [1]		
Borates are used in the glass, frits and ceramics production [23]		
Silica sand is used for fibreglass, chemicals, gasfilling and increasing oil and gas drillings and the production of silicone steel [23]		Ferrosilicon could be substituted by Aluminum, silicon cardide and siliconmangnese. In semiconductors Gallium arsenide and Germanium can substitute Silicon [1]
Ammonia used for fertilizer and in the production of plastics, explosives and other chemicals[1]	Availability of nitrogen is unlimited [1]	Nitrogen has no substitute [1]
Fluorspar is used for chemicals, steel, aluminum and glass and glass fibers production [23]		Several materials can replace Fluorspar fluxes [1]
Chlorine is used in many organic an anorganic compounds [18]		
Bromine compounds used in flame retardants, drilling fluids and brominated pesticides [1]		Chlorine and iodine should be substitutes for Bromine in few chemical reactions, no comparable substitutes for bromine in several oil and gas well comletion, some materials could be used as substitutes for fire retardments [1]
Iodine used in liquid crystals displays (LCD) and as x-ray contrast media, synthetic fabric treatments [1]	Increasing prices in recent years owing to high demand (estimated 3.5% and 4% per year during the next decade) [1]	Cesium is used as an alternative for iodine [1]
Astatine is used in nuclear medicine serve for the ray treatment of malicious Tumore [18]	Radioactive substance (use and disposal costs at eol) [Expert Judgement]	
Helium used for cooling applications (e.g. in MRTs), in welding applications, lacertechnique, deep-sea diving, measurement instrumentation, as on-drive gas, for superconductive materials and sensors and in medicine [24]	Price increases of 5-10% and price increasing are estimated, plants in Algeria with production problems but worldwide eight new helium plants are scheduled between 2011 and 2017 [1]	No substitute for Helium in cryogenic applicatins. Argon can substitute helium in welding, hydrogen can be substitute helium in some lighter-than-air applications and as substitute in deep-sea diving applications [1]
Neon used as filling gas in electric bilbs, in composition with Helium it is used in lacer applications [18]		
Together with nitrogen it is used in electric bulbs. It is also used in laser applications and for welding as shieling gas [18]		
Krypton used as filling gas for halogen lamps and into gas-discharge tubes [18]		
Xenon used in halogen electric light bulbs (e.g. automobile headlights), as narcotic and the radioactive isotop Xe-133 used as tracer in medicine, xenon could also be used for electrostatic rocket engines [18]		
	Radioactive substance (use and disposal costs at eol) [Expert Judgement]	

Sources: Ref.No.

Angerer, G., Erdmann, L., Marscheider-Weidemann, F., Scharp, M., Lüllmann, A., Handke, V. und Marwede, M. (2009): Rohstoffe für Zukunftstechnologien - Einfluss des branchenspezifischen Rohstoffbedarfs in rohstoffintensiven Zukunftstechnologien auf die zukünftige Rohstoffnachfrage, Stuttgart, Fraunhofer IRB Verlag, 2009, abgerufen am 18.01.2012, http://www.isi.fraunhofer.de/isi-de/n/download/publikationen/Schlussbericht_lang_20090515_final.pdf. [5]

Auswärtiges Amt (2012): Auswärtiges Amt - Reise- und Sicherheitshinweise: Länder A-Z, 05.04.2012, abgerufen am 05.04.2012, http://www.auswaertiges-amt.de/DE/Laenderinformationen/SicherheitshinweiseA-Z-Laenderauswahlseite_node.html. [2]

Barbalance, K. (2012): Periodic Table of Elements: Lanthanum - La, 05.04.2012, abgerufen am 05.04.2012, http://environmentalchemistry.com/yogi/periodic/La.html. [13]

Behrendt, Siegfried, Scharp, M., Kahlenborn, Walter, Feil, Moira, Dereje, Cornelia, Bleischwitz, Raimund und Delzeit, Ruth (2007): Seltene Metalle. Maßnahmen und konflikte zur Lösung des Problems konfliktverschärfender Rohstoffausbeutung am Beispiel Coltan, Dessau, Umweltbundesamt, 2007, abgerufen am 02.05.2012, http://www.umweltdaten.de/publikationen/fpdf-l/3182.pdf. [15]

Dacha Strategic Metals Inc. (2012): Dacha - Rare Metals - Lutetium, 05.04.2012, abgerufen am 05.04.2012, http://www.dachacapital.com/Rare-Metals/Lutetium/default.aspx. [20]

Deutsches Institut für Edelmetalle & Technologiemetalle (2012): Seltene Erden, 05.04.2012, abgerufen am 05.04.2012, http://www.edelmetallinstitut.com/seltene_erden.html. [19]

Elsner, H., Melcher, F., Buchholz, P. und Schwarz-Schampera,, U. (2010): Elektronikmetalle – zukünftig steigender Bedarf bei unzureichender Versorgungslage *In: Commodity Top News*, Band 33, 04.2010, S. 1–13. [7|

European Commission. Enterprise and Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, EC, Brussels, European Commission, DG Enterprise and Industry, 2010, abgerufen am 01.05.2012, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v-b_en.pdf. [23]

Faulstich, Martin, Mocker, Mario, Pfeifer, Stephanie, Köglmeier, Markus und Enger, Sebastian (2010): r^3 - Innovative Technologien für Ressourceneffizienz - Strategische Metalle und Mineralien, München, Technische Universität München, 2010, abgerufen am 01.05.2012, http://www.bmbf.de/pubRD/informationspapier_bmbf_r3.pdf. [21]

Goodman, Paul (2006): Review of Directive 2002/95/EC (RoHS) Categories 8 and 9 - Final Report, European Commission, DG Environment, 2006, http://ec.europa.eu/environment/waste/pdf/era_study_final_report.pdf. [25]

Humphries, Marc (2011): Rare Earth Elements: The Global Supply Chain, Congressional Research Service, 2011, http://www.fas.org/sgp/crs/natsec/R41347.pdf. [11]

Institut für Arbeitsschutz der Detuschen Gesetzlichen Unfallversicherung (2012): GESTIS-Stoffdatenbank. Gefahrstoffinformationen der Deutschen Gesetzlichen Unfallversicherung, 05.04.2012, abgerufen am 05.04.2012, http://www.dguv.de/ifa/de/gestis/stoffdb/index.jsp. [6]

ISE - Institut für Seltene Erden und Metalle (2012): Institut für Seltene Erden, 05.04.2012, abgerufen am 05.04.2012, http://www.institutselteneerden.com/selteneerden/Cer.html. [16]

Lenntech BV (2012): PSE - Periodensystem der Elemente, 05.04.2012, abgerufen am 05.04.2012, http://www.lenntech.de/pse/pse.htm. [4]

Lutz, Ferdinand (2010): Die künftige Verfügbarkeit knapper, strategisch wichtiger Metalle. Risiken und Herausforderungen, Bonn, Denkwerk Zukunft - Stiftung kulturelle Erneuerung, 2010, http://www.denkwerkzukunft.de/downloads/Verf%C3%BCgbarkeit_von_Metallen.pdf. [14]

Messer Group GmbH (2008): Helium - das besondere Element, Krefeld, Messer Group GmbH, 2008, http://www.messergroup.com/de/Daten/Fachbroschueren/Spezialgase/Helium_das_besondere_Element.pdf. [24]

Nauckhoff, Mikael Henrik (2011): Strategische Metalle und Seltene Erden: Investieren in Technologiemetalle und Hightech-Metalle: Indium, Wismut, Terbium & Co, Finanzbuch Verlag GmbH, 2011, ISBN: 9783898796477. [17]

Schnabel, Frieder, von Geibler, Justus, Rohn, Holger, Meier, Jana, Wiesen, Klaus, Ziema, Elina, Pastewski, Nico und Lettenmeier, Michael (2011): Resource Efficiency Atlas. An international perspective on technologies and products with resource efficiency potential, Wuppertal, Wuppertal-Inst. für Klima, Umwelt, Energie, 2011, abgerufen am 02.05.2012, http://www.wupperinst.org/uploads/tx_wibeitrag/ws44e.pdf. [12]

Schott, Benjamin (2010): Lithium – begehrter Rohstoff der Zukunft - Eine Verfügbarkeitsanalyse, Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg, 2010, abgerufen am 02.05.2012, http://www.zsw-bw.de/fileadmin/ZSW_files/Infoportal/Informationsmaterial/docs/Risikoanalyse%20Lithium_05_08_2010.pdf. [3]

Schüler, Doris, Buchert, Matthias, Liu, Ran, Dittrich, Stefanie und Merz, Cornelia (2011): Study on Rare Earths and Their Recycling, Freiburg, Öko-Institut e.V., 2011. [8]

Seilnacht (2012): Periodensystem der Elemente, 05.04.2012, abgerufen am 05.04.2012, http://www.seilnacht.com/Lexikon/psframe.htm. [18]

Tharumarajaha, Ambalavanar und Koltun, Paul (2011): Cradle to Gate Assessment of Environmental Impact of Rare Earth Metals, in: {Australian Life Cycle Assessment Society Inc.} (Hrsg): *7th Australian Conference on Life Cycle Assessment, Conference Proceedings, Melbourne: Life Cycle Assessment: Revealing the secrets of a green market*, Melbourne, 2011, S. 1–5, abgerufen am 19.10.2011, http://www.conference.alcas.asn.au/2011/Tharumarajah.pdf. [10]

The International Copper Study Group (ICSG) (2010): The World Copper Factbook 2010, Lissabon, International Copper Study Group, 2010, abgerufen am 15.02.2012, http://www.icsg.org/index.php?option=com_docman&task=doc_download&gid=278&Itemid=61. [22]

U.S. Geological Survey (2011): Mineral Commodity Summaries 2011, Washington, U.S. Geological Survey and Department of the Interior, 2011. [1]

Vbw Bayern (2011): Rohstoffsituation Bayern: Keine Zukunft ohne Rohstoffe, vbw - Vereinigung der bayerischen Wirtschaft e.V., 2011, abgerufen am 22.09.2011, www.vbw-bayern.de. [9]

D | Befragungstool – Sustainable Healthcare Products Trade-Off Matrix

Corresponding meaning of values to be chosen from dropdown menus in the white cells of the matrix.	
Much More Important =	10
More Important =	5
Approx Equal Importance =	1
Less Important =	0.2
Much Less Important =	0.1

Approach:
1) Read the matrix from ►LEFT to RIGHT.
2) Please choose one value from dropdown in the white cells ONLY. Please do not change values in grey cells.
3) Compare each indicator from column A to each indicator in the respective row.

Examples:
- 'Speed of product' is e.g. (choose 5=) more important than 'Energy consumption'.
- 'Noise' is e.g. (choose 0.2=) less important than 'Hazardous Substances'.

Sustainable Product Characterization Indicators	Product in terms of Scanning/ Processin	Energy Consumption	Waste Materials	Noise	Hazardous Substances	Fresh Water	Restricted Materials	Limited Materials	Ecological Significance (environmenta l impact)	End of Life Options	User Friendliness	Innovativeness	Image Quality	Clinical Performance
Speed of Product in terms of Scanning/ Processing		1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Energy Consumption	1,0		1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Waste Materials	1,0	1,0		1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Noise	1,0	1,0	1,0		1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Hazardous Substances	1,0	1,0	1,0	1,0		1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Fresh Water	1,0	1,0	1,0	1,0	1,0		1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Restricted Materials	1,0	1,0	1,0	1,0	1,0	1,0		1,0	1,0	1,0	1,0	1,0	1,0	1,0
Limited Materials	1,0	1,0	1,0	1,0	1,0	1,0	1,0		1,0	1,0	1,0	1,0	1,0	1,0
Ecological Significance (environmental impact)	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0		1,0	1,0	1,0	1,0	1,0
End of Life Options	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0		1,0	1,0	1,0	1,0
User Friendliness	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0		1,0	1,0	1,0
Innovativeness	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0		1,0	1,0
Image Quality	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0		1,0
Clinical Performance	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	
Reliability	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Service	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Reimbursement Capability	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Capability for Treatment/ Diagnose Symtoms of New Disease (Trends)	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Design/ Product Appearance	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Product Campaigns/ Customer Education	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0

Reliability	Service	Reimbursement Capability	Treatment/ Diagnose Symtoms of New Disease (Trends)	Design/ Product Appearance	Product Campaigns / Customer Education	**Indicator description**
1,0	1,0	1,0	1,0	1,0	1,0	describes data acquisition and calculation/ development of an image ready to be viewed/ time until reagent reacts to input substance/ signal transferred
1,0	1,0	1,0	1,0	1,0	1,0	encompasses all energy consumption changes during all life cycle stages for the defined functional unit in LCA.
1,0	1,0	1,0	1,0	1,0	1,0	encompasses all type, quantity and quality of waste generation changes during all life cycle stages (waste water, recycling, refurbishing, incineration, reuse, landfill).
1,0	1,0	1,0	1,0	1,0	1,0	considered if level of noise reaches level in which workplace-safety measures have to be taken (during production and use phase)
1,0	1,0	1,0	1,0	1,0	1,0	These substances can be solids, liquids, gases, mists and fumes, as well as biological agents and dusts in substantial concentrations. SVHC are substances having hazardous properties of very high concern for human health and environment. These substances are categorized within REACH as under: (a) Substances meeting the criteria to be considered as carcinogenic, mutagenic or toxic for reproduction (CMR categories 1/2). (b) Substances meeting the criteria to be considered as persistent, bioaccumulative or toxic (PBT) or which are very persistent and very bioaccumulative (vPvB). (c) Substances, such as those having endocrine disrupting properties, or those having persistent, bioaccumulative and toxic properties or very persistent and very bioaccumulative (vPvB) properties or substances which are identified as causing serious and irreversible effects to humans or the environment which are equivalent to those of other substances listed under (a) or (b) on a case-by-case basis. (d) Persistent organic pollutants (POPs) are vPvB substances and shall be included in authorisation process. further following the definition of Kalerlah (UBA): e) Substances meeting the criteria to be considered as carcinogenic, mutagenic or toxic for reproduction (CMR categories 3). f) substances which are considered especially toxic (T+) g) which cause irritation to raspiratory organs or skin (only substances with significant effects)
1,0	1,0	1,0	1,0	1,0	1,0	Describes all water consumed in or for the product during all life cycle stages, which is characterized by low concentrations of dissolved salts and other dissolved solids relative to it severity impact (water availability)
1,0	1,0	1,0	1,0	1,0	1,0	defines materials present in a product that are prohibited or restricted by regulation. Base review on latest BOMcheck restricted an declarable substances list.
1,0	1,0	1,0	1,0	1,0	1,0	defines materials which are economically, politically or naturally only limited available, e.g. rare earths, conflict metals
1,0	1,0	1,0	1,0	1,0	1,0	the environmental impact(s) of the products and all significant related processes within ist all life cycle stages.
1,0	1,0	1,0	1,0	1,0	1,0	describe the options in phase after usage, e.g. collection by Siemens, recycling, refurbishment, disposal of modules etc.
1,0	1,0	1,0	1,0	1,0	1,0	includes items such as handling and positioning (ergonomics), ease of visibility of controls, ease of use, positioning of switches/buttons, ease of use/ understand user manual etc.
1,0	1,0	1,0	1,0	1,0	1,0	defines all characteristics of the product which are designed or arranged that offer new or additional features. It describes the general innovativeness/ and in comparison to the predecessor
1,0	1,0	1,0	1,0	1,0	1,0	describes quality of all means of visualization or treatment serving for a medical diagnosis, e.g. the result accuracy by color-coding from diagnostic reagents or body scans by MRI, etc.
1,0	1,0	1,0	1,0	1,0	1,0	describes the degree to which the product meets the customer environment; i.e. work without delay, adapt to customer specific workloads, use the features offered, etc.
	1,0	1,0	1,0	1,0	1,0	describes the system robustness and downtime (availability of the system (interruptions/downtime) in routine use scenario)
1,0		1,0	1,0	1,0	1,0	describes the level of assistance offered, e.g. remote access. Includes the modularity which describes ease of repair, maintenance, purchase of spare parts, ability to export results data etc.
1,0	1,0		1,0	1,0	1,0	describes the ability of the customer to invoice the service or the product to the patient and to the health service sector/ health insurance; the degree of acceptance of the public institutions of the service delivered by the product
1,0	1,0	1,0		1,0	1,0	describes the possibility to image/diagnose/treat new disease trends
1,0	1,0	1,0	1,0		1,0	describes function developing the "look and feel" of the product
1,0	1,0	1,0	1,0	1,0		refers to advertising and communication, as well as the possibility to influence customer attitudes

E Überblick über die Fragebogenitems aus der Arbeit von Schieban (2011)

	Part	Indicator	Question	Question	
	Einleitung		**If one question does not apply to your product or system, please leave the according response blank.**		
			Medical Personnel / Development Team		select
			Imaging Equipment / Therapy Equipment / Reagents		select
			Magnetic Resonance / Computed Tomography / Diagnostics		select
A	**Personal Information developmen t team)**		Choose the category or combination of categories which best describes your job position	010	categories
			How do you rate your knowledge of the overall functionality of the product?	020	likert
			How do you rate your knowledge of the technology in the product?	030	likert
			How do you rate your knowledge of the application supported by the product?	040	likert
			How do you rate your knowledge of the target market/ customer of the product?	050	likert
A	**Personal Information (medical team)**		Choose the category or combination of categories which best describes your job position	010	categories
			Have you had a chance to experience the overall functionality of the system?	020	open
			Have you personally worked with the system?	030	y/n
			What is the volume of exams/tests read/performed per month at your site in your daily clinical routine with imaging/therapy/diagnostics equipment?	061	likert
			If possible, please indicate a number	062	open
			What type of hospital/ practice do you work in?	071	categories
			How many beds does your institution have?	072	categories
B	**Categorization of the product (development team)**		Please state the name of the product that you evaluate	010	open
			Have you worked with the predecessor of the product stated above?	021	y/n
			If applicable, state the name of the previous system (in the following called “predecessor”)	022	open
			Please specify the last PLM development stage that the product has passed	030	open
		Filter: DX	Please state the category or combination of categories that best applies to the product stated in Question B010	041	categories
		Filter: DX	Please further specify the sub-category that best applies to the product evaluated	042	open
		Filter: DX	Please describe the environment in which the product will be used	050	open
B	**Categorization of the product (medical team)**		Please state the name of the product that you evaluate	010	open
			Have you previously worked with a system similar to the one stated above?	021	y/n
			If applicable, state the name and manufacturer of this previous product that you evaluate (in the following called “predecessor”)	022	open
		Filter: DX	Please state the category or combination of categories that best applies to the product stated in Question B010	041	categories
		Filter: DX	Please further specify the sub-category that best applies to the product evaluated	042	open
		Filter: DX	Please describe the environment in which the product will be used	050	open

The following sections regard information on your product; Section C asks for a general overview of the system, section D asks for more specific information.

C	Information about the product (general part)	**Innovativeness**	How do you rate the new or rearranged functionalities of your system (Functionalities describe the variety, quality, and relevance of improved or new diagnosis opportunities)	011	likert
gene		**Capability for treatment/**	How do you rate the new or rearranged functionalities of your system compared to its predecessor?	012	likert
			Please state its key applications/functionalities:	013	open
		Image Quality (general)	How do you rate the overall image quality of your system? (Image quality describes the quality of all means of visualization serving for a medical diagnosis, e.g. the body scans by MRI)	021	likert
			How do you rate the overall image quality of your system compared to the predecessor?	022	likert
		Clinical Performance	How do you rate the extent to which the system will meet your clinical requirements? (Clinical requirements describe the degree to which the system meets your environment, i.e. work without delay, usage of features offered, etc.)	031	likert
			How do you rate the extent to which the system will meet your clinical requirements compared to its predecessor?	032	likert
		Reimbursement	How do you rate the extent to which the health insurance compensates for the clinical results provided by the system?	041	likert
			How do you rate the extent to which the health insurance compensates for the clinical results provided by the system compared to its predecessor?	042	likert
		Service	How do you rate the overall technical service support of the system? (Technical service support describes the level of assistance offered, e.g. remote access)	051	likert
			How do you rate the overall technical service support of the system compared to its predecessor?	052	likert
			How do you rate the individualisation/ adaptability of your service contracts?	053	likert
		Filter: Developers	How do you rate the modularity of the product, e.g. ease of replacement of parts, ease of repair, maintenance, purchase of spare parts, ability to export results data?	054	
		Developers	How do you rate the modularity of the product compared to the predecessor?	055	
	Information about the product (general part)	**Design/ Product Appearance**	Please rate the following statements compared to its predecessor system:		
			The product design/ appearance is...		
			non-structured |1|...|10| structured	061	likert
			low-quality processed |1|...|10| high-quality processed	062	likert
			unappealing |1|...|10| sympathetic	063	likert
			worrisome |1|...|10| trustworthy	064	likert
			Please state key design/appearance features that have been rated above:	065	open
		Product Campaigns/ Customer Education	Please indicate the information and communication material that you are familiar with:	070	categories
			Please rate the following statements: Product information and communications (are)...		
			unclear and vague |1|...|10| clear and precise	071	likert
			uninteresting |1|...|10| informative	072	likert
			not practical (or does not provide useful/additional information) |1|...|10| practical	073	likert
			do not increase awareness for use/ handling/ diagnosis/ test treatment options |1|...|10| increase awareness	074	likert
			"Green functionalitites" are unimportant compared to individual settings |1|...|10| The "green functionality" of a product is very important to me	075	likert
			Reusage and recycling are unimportant to me |1|...|10| Reusage and recycling of the product are very important to me	076	likert
		User Friendliness (general)	How do you rate the overall user friendliness of the system? (User friendliness includes items such as ergonomics, ease of visibility of controls, positioning of switches/buttons, ease of use/understanding of user manual)	081	likert
			How do you rate the overall user friendliness of the system compared to its predecessor?	082	likert
D	Information about the product	**Reliability**	How do you rate the reliability/stability of the system in your daily clinical routine? (Reliability/stability describes the system robustness and downtime; availability of the system and interruptions in daily clinical routine)	091	likert
			How do you rate the speed of the system in terms of scanning or processing?	092	likert
			How do you rate the speed of the system in terms of post processing?	093	likert
		Filter: IM, TH	For imaging and therapy equipment: How do you rate the availability of the system? Please compare robustness and downtime to the predecessor performance.	0941	likert
		Filter: RE	For reagents: How do you rate the availability of the system? Please compare durability to the predecessor performance.	0942	likert
		User Friendliness (specific)	How do you rate the software functionalities of the system?	101	likert
			How do you rate the software functionalities compared to the predecessor?	102	likert
			How do you rate the handling and positioning options of the patient/test?	103	likert
			How do you rate the handling and positioning options of the patient/test compared to the predecessor?	104	likert
			How do you rate the visibility and handling of controls/switches/buttons/cassettes, ease of use of the system?	105	likert
			How do you rate the visibility and handling of controls/switches/buttons/cassettes, ease of use of the system compared to the predecessor?	106	likert
			How do you rate the applicability and comprehensibility of the manual?	107	likert
			How do you rate the applicability and comprehensibility of the manual compared to the predecessor?	108	likert
			How do you rate the patient/test throughput of your system?	109	likert
			How do you rate the patient/test throughput compared to the predecessor product?	110	likert
		Image Quality (spec)	How do you rate the features of your imaging equipment that contribute to the improvement of the overall imaging quality compared to the predecessor?	1111	likert
		Filter: IM, DX, TH	Please state these features:	1121	open
			How do you rate the features of your diagnostic equipment, that contribute to the improvement of the overall diagnostic quality compared to the predecessor?	1112	likert
			Please state these features:	1122	open
			How do you rate the features of your therapy equipment, that contribute to the improvement of the overall therapy quality compared to the predecessor?	1113	likert
			Please state these features:	1123	open

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