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EU Raw Materials Week
Brussels, 12. November 2018

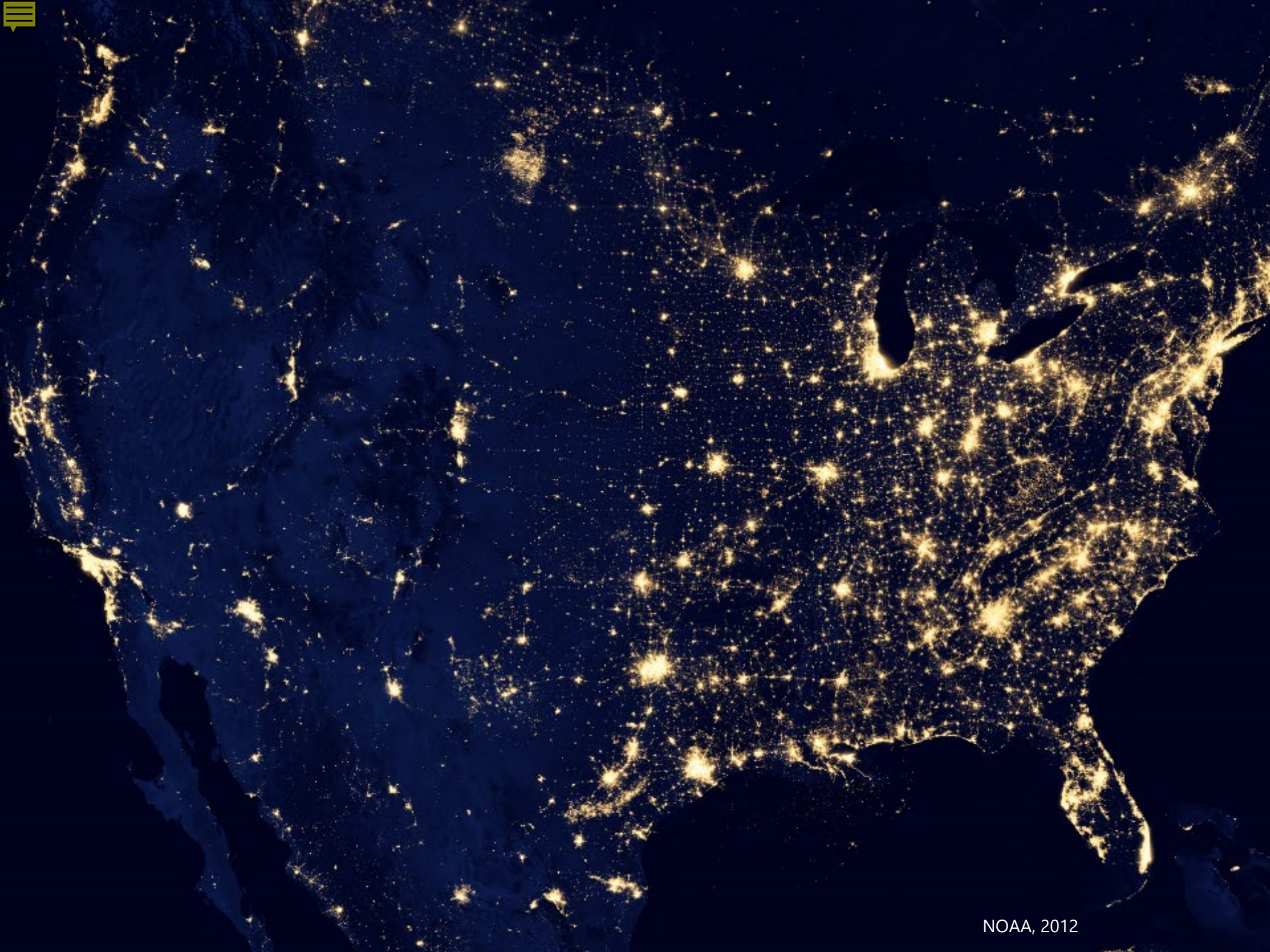
Importance of critical raw materials, future demand and supply

Dr. Peter Buchholz, German Mineral Resources Agency (DERA) at the Federal Institute for Geoscience and Natural Resources (BGR)

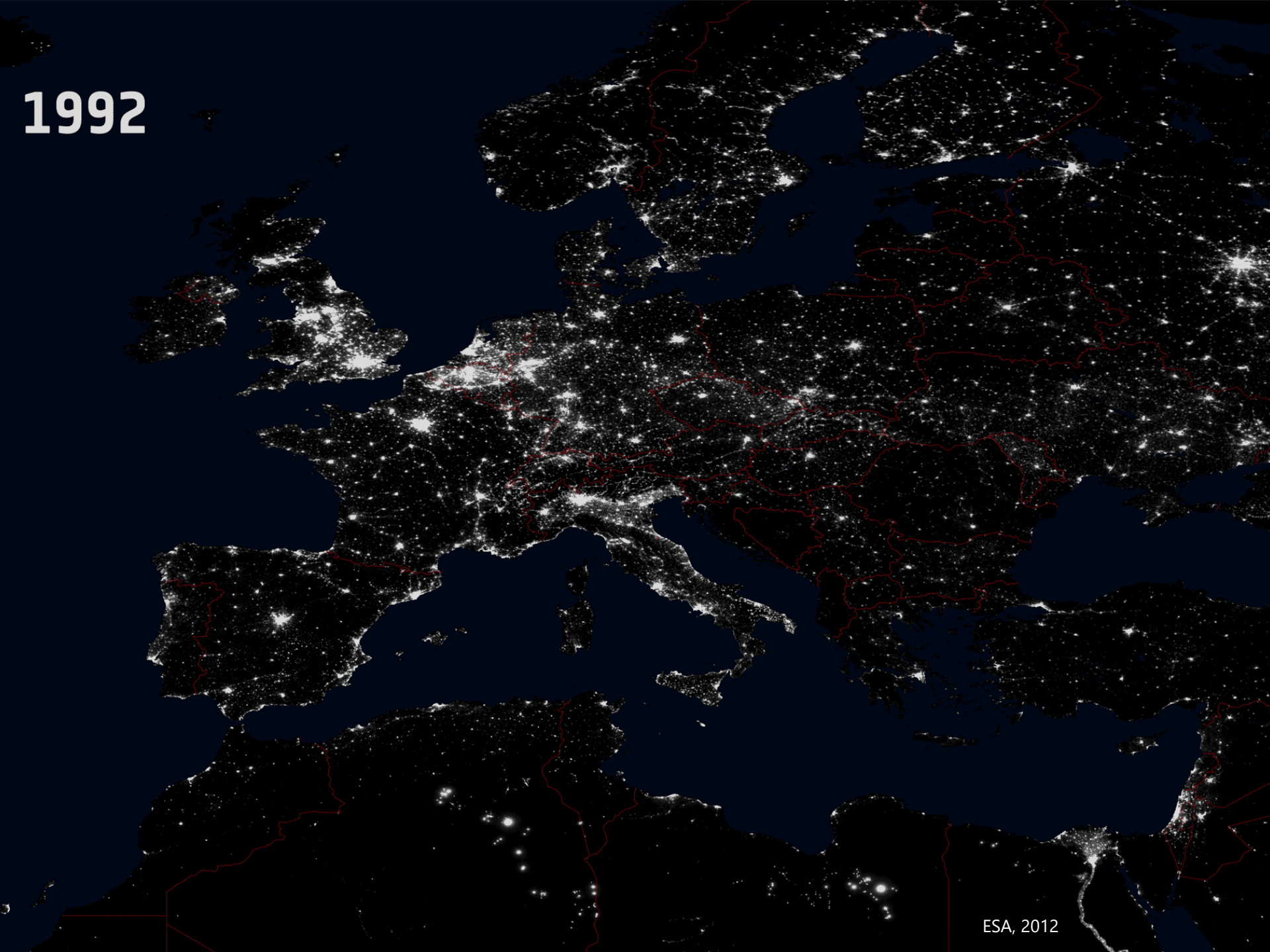
Bundesministerium für Wirtschaft und Energie

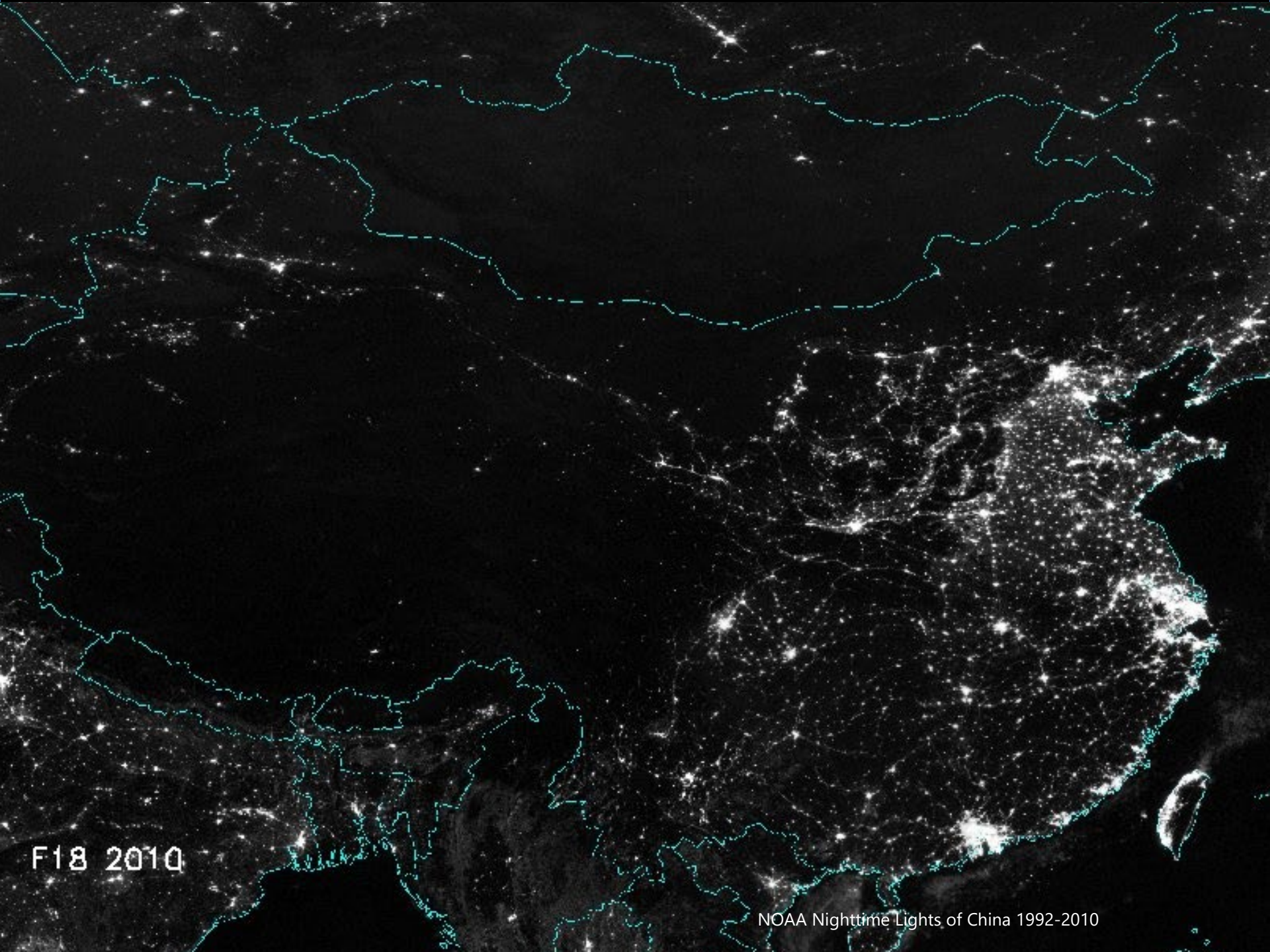
Die Bundesanstalt für Geowissenschaften und Rohstoffe ist eine technisch-wissenschaftliche Oberbehörde im Geschäftsbereich des Bundesministeriums für Wirtschaft und Energie (BMWi).

NASA, 2012



NOAA, 2012

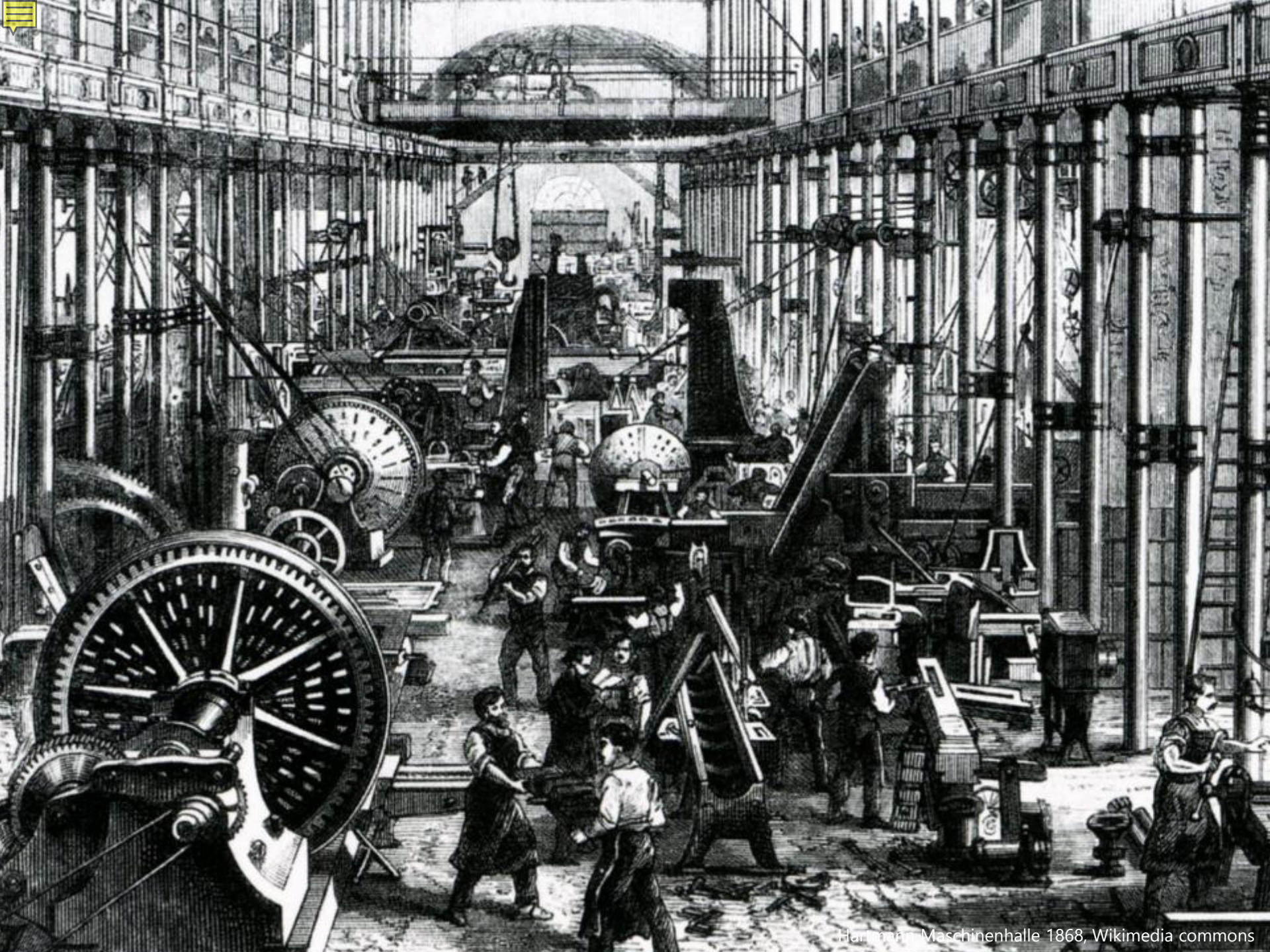

1992
ESA, 2012



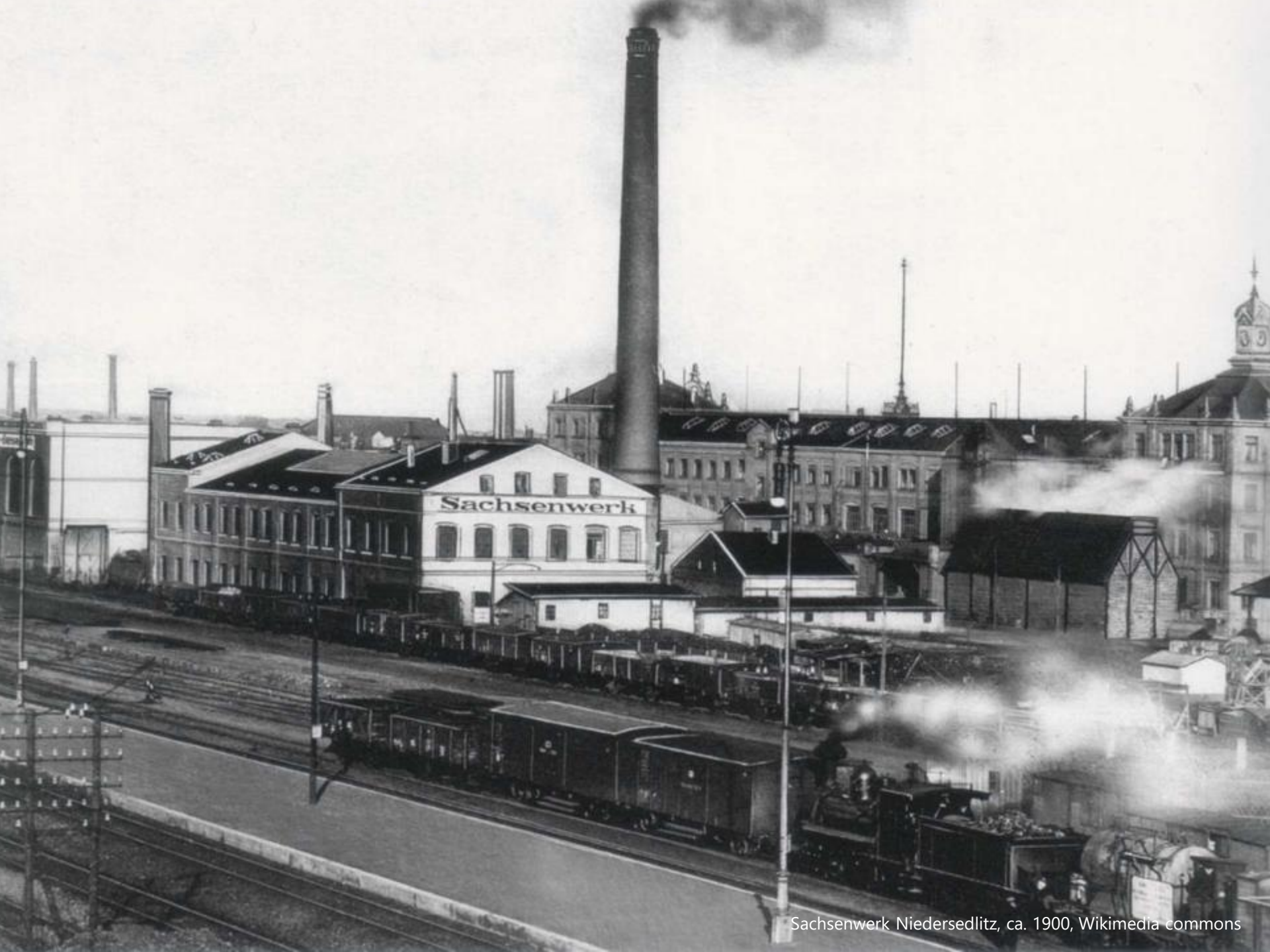
NOAA Nighttime Lights of China 1992-2010

NASA_gallery-fotolia

NASA/NOAA 2009



Hartmann, Maschinenhalle 1868, Wikimedia commons



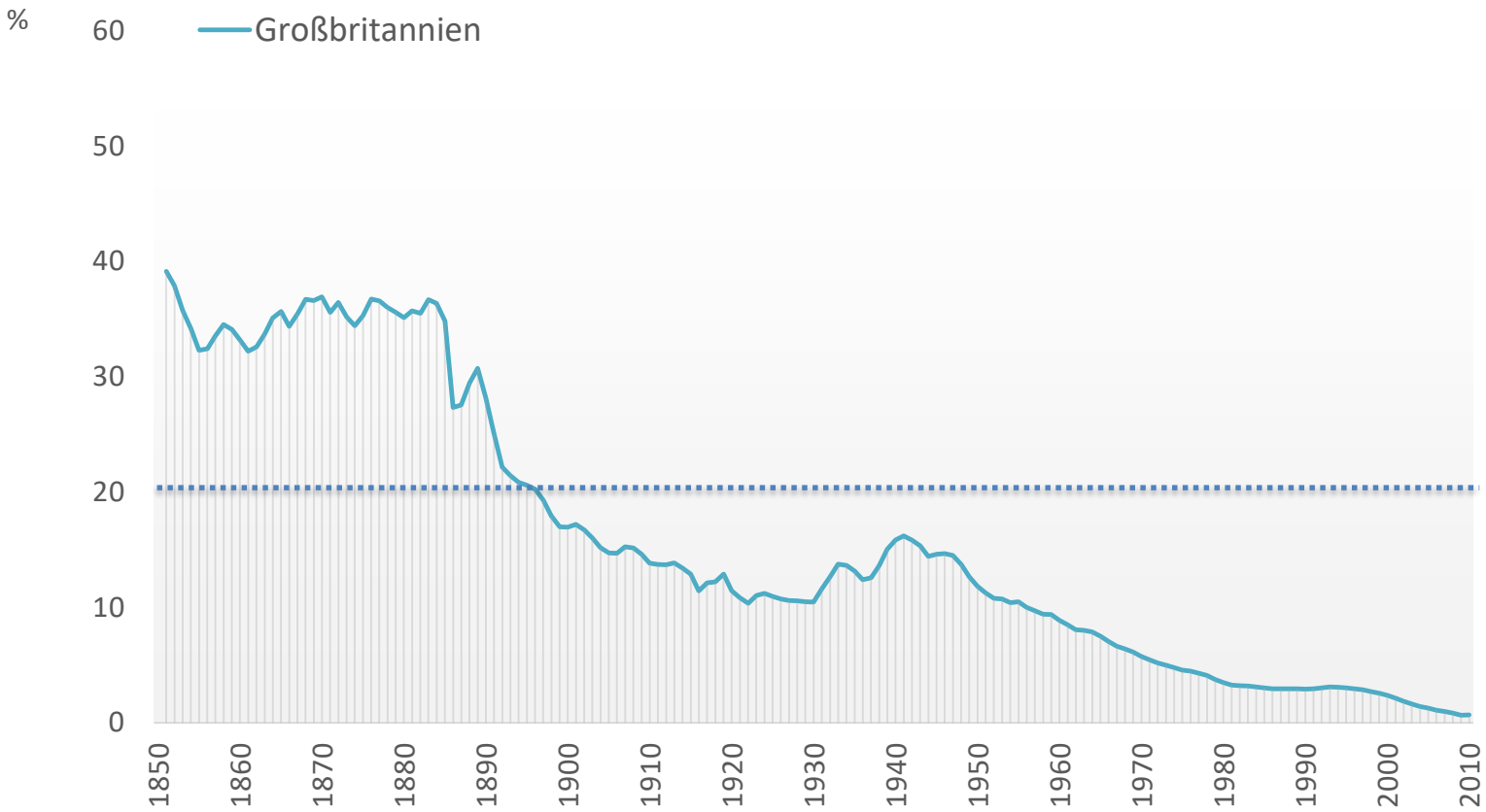
Sachsenwerk Niedersedlitz, ca. 1900, Wikimedia commons

Charles Clyde Ebbets, Lunch atop a Skyscraper, 1932

SeanPavonePhoto-fotolia

Demand of metals in industrialised countries as a share of global demand

Considered metals: Aluminium, steel, copper, zinc and tin



University of Bonn, M. Stürmer, contracted by DERA, 2012

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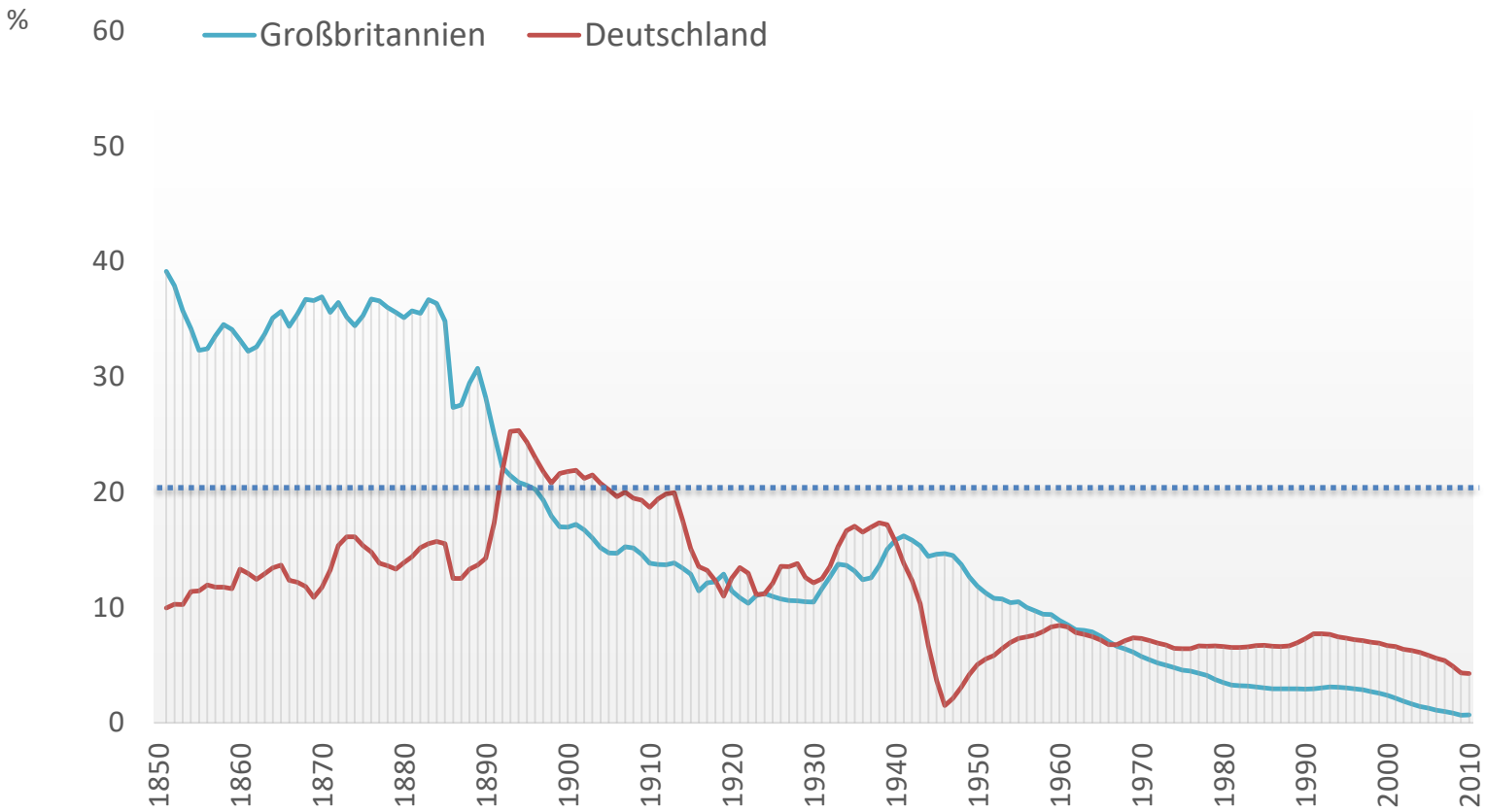

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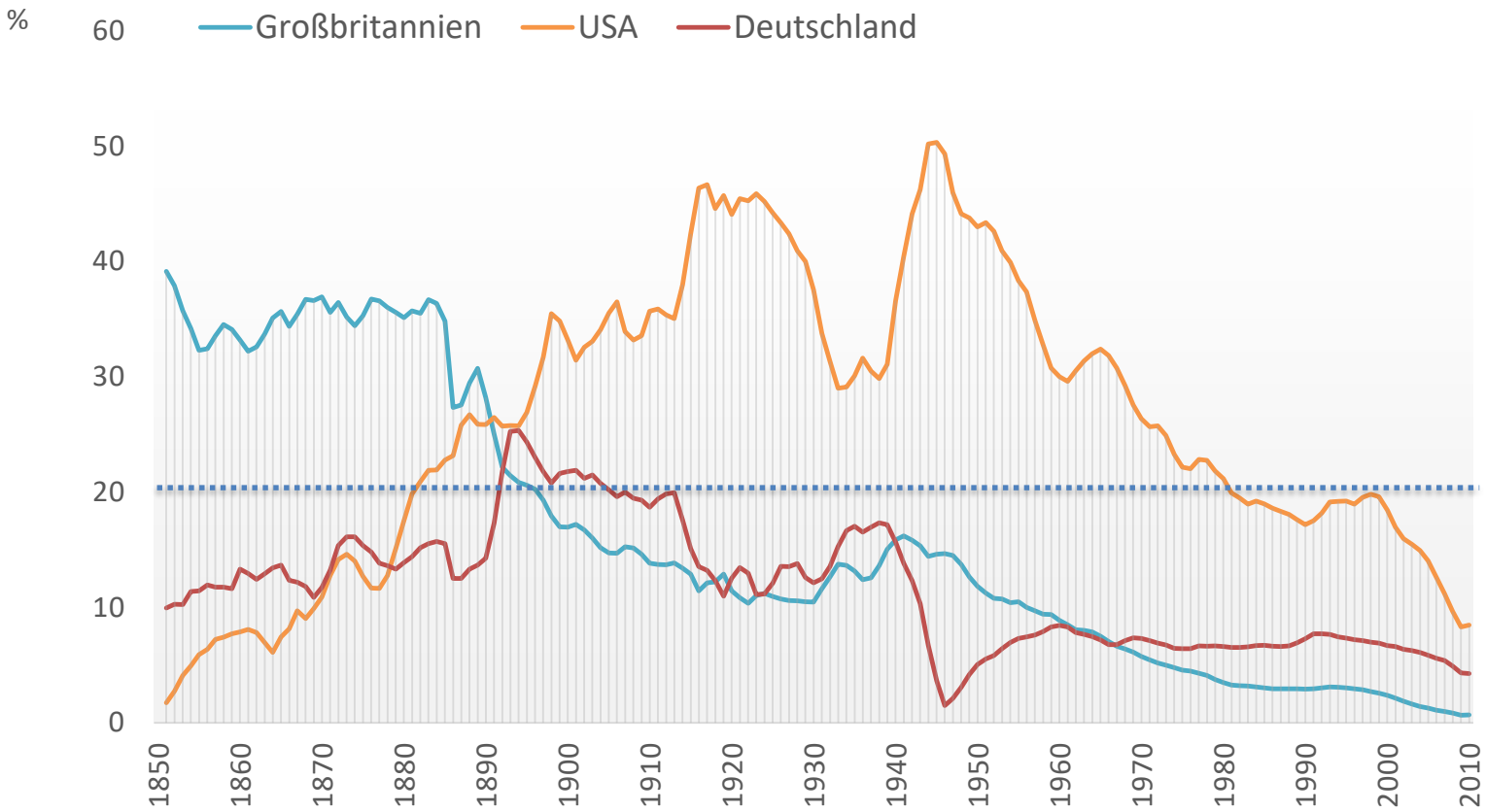

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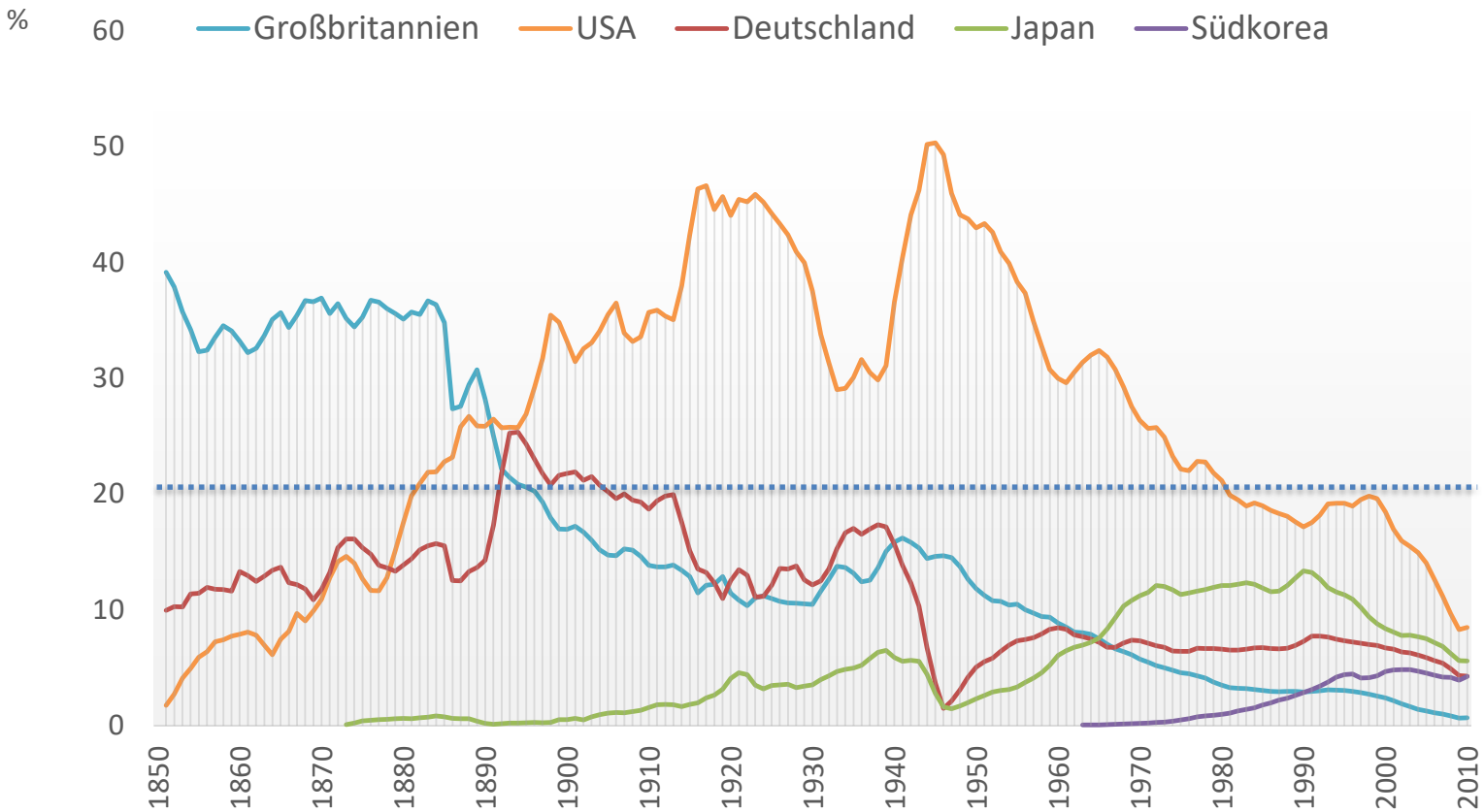
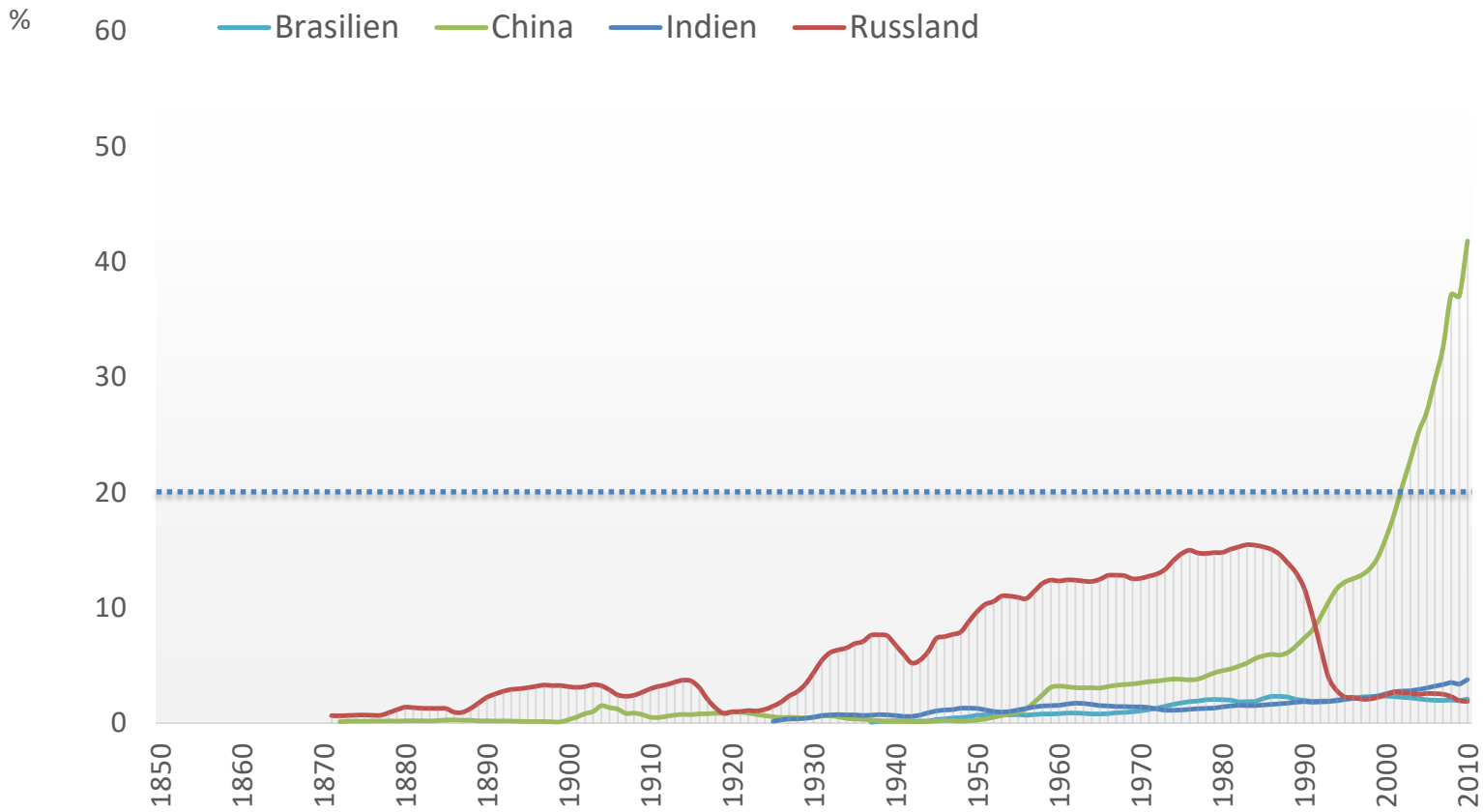


University of Bonn, M. Stürmer, contracted by DERA, 2012

Demand of metals in emerging countries as a share of global demand

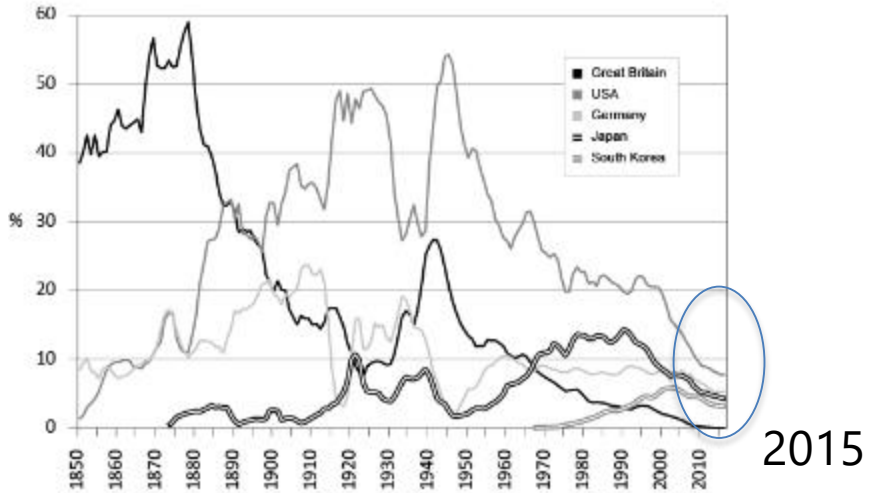
Considered metals: Aluminium, steel, copper, zinc and tin



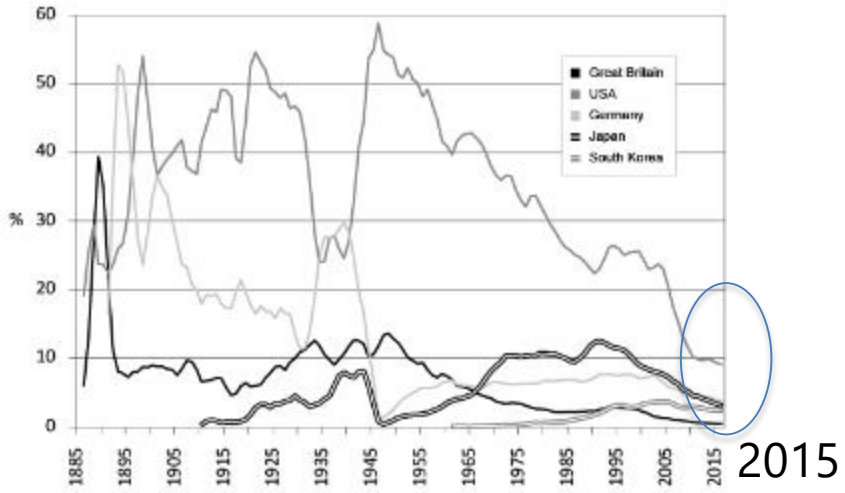
University of Bonn, M. Stürmer, contracted by DERA, 2012

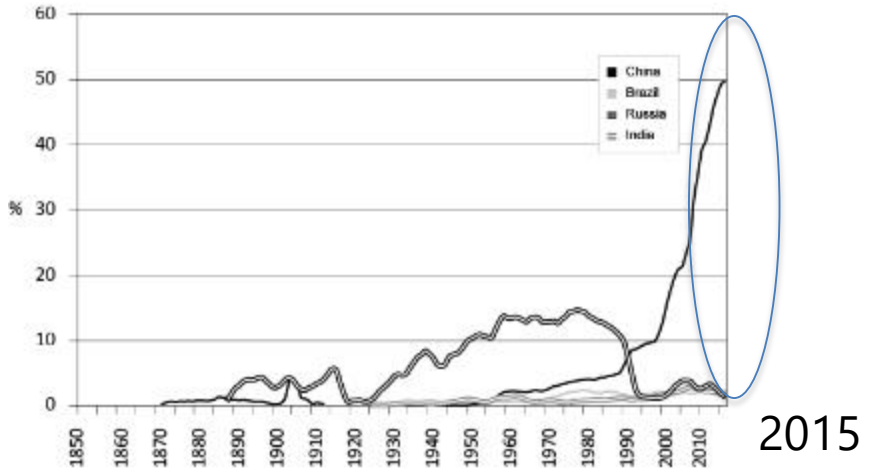
Screening of raw material demand based on industrialization

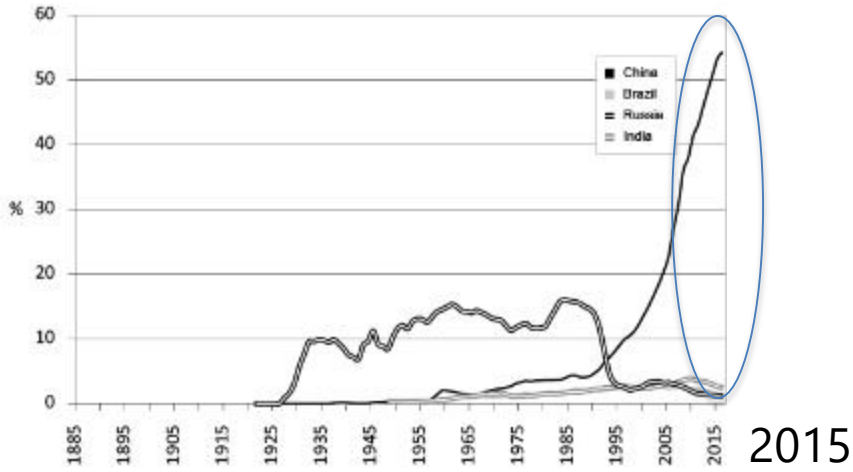
a) Share of global demand for copper



b) Share of global demand for aluminium



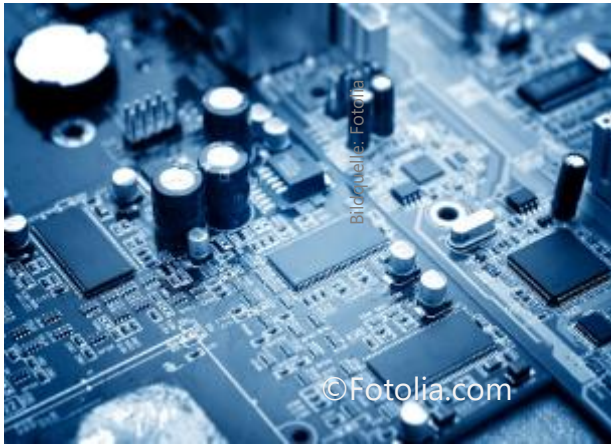




Buchholz & Brandenburg, CIT, 2018

DERA Deutsche Rohstoffagentur
Bundesanstalt für Geowissenschaften und Rohstoffe

Key and future technologies are massively driving future demand for mineral raw materials



Bildquelle: Fotolia

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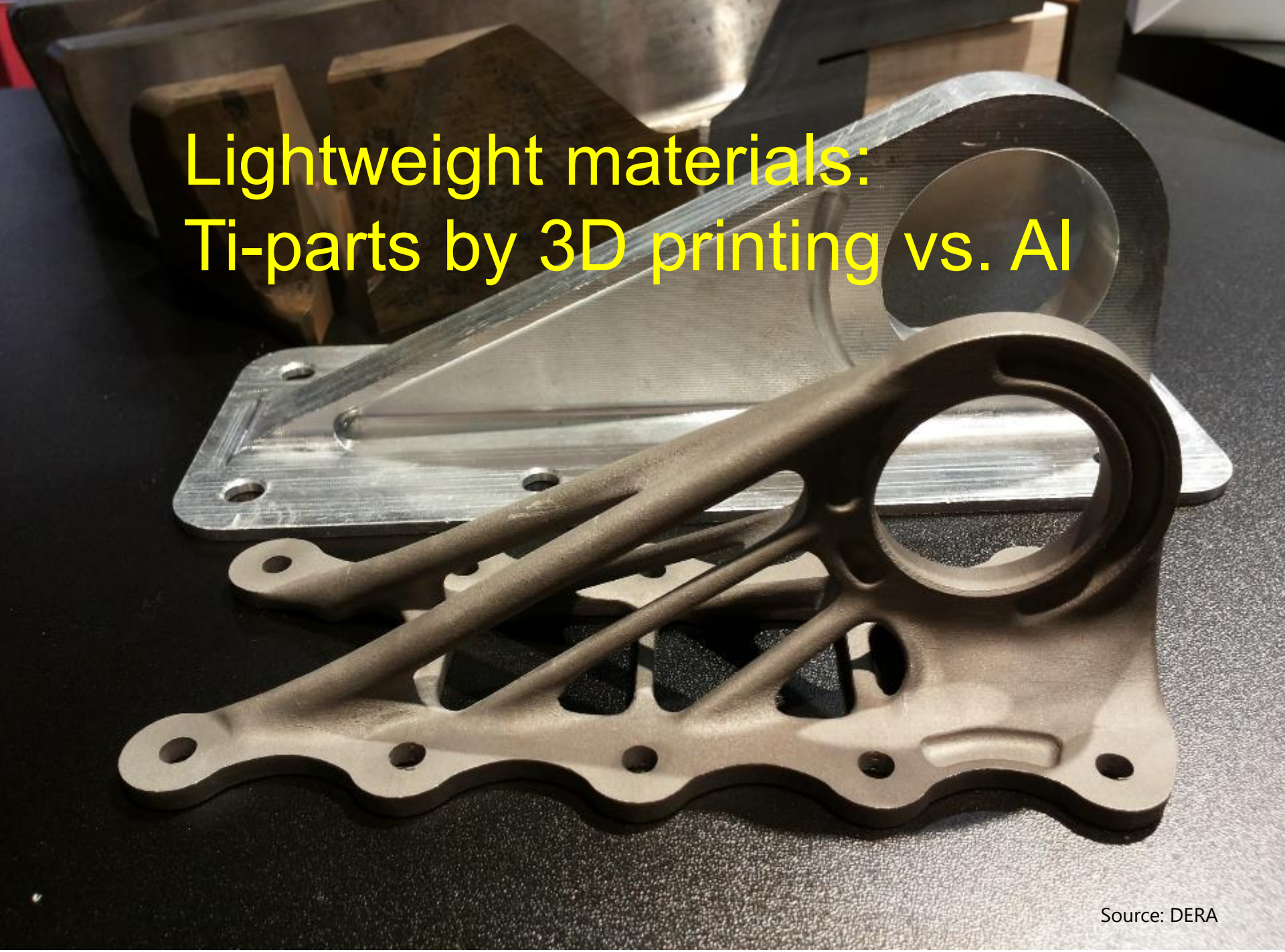
Superalloys:
Ni, Co, Cr, Mo, Nb,
W, Ta, Ti, Re
Source: fotolia

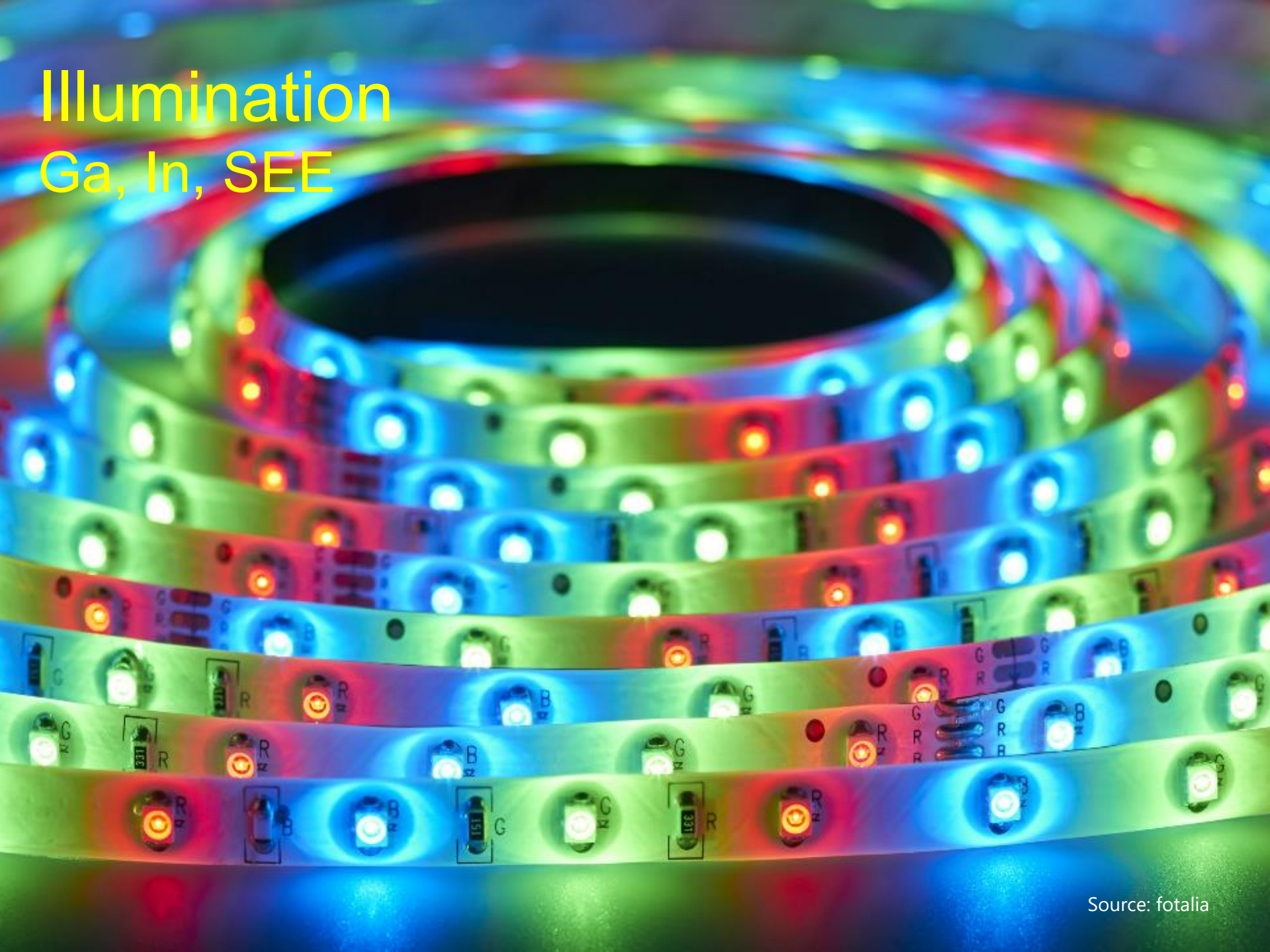

Lightweight materials:
Ti-parts by 3D printing vs. Al
Source: DERA

Industry 4.0 - Digitalization Germanium

Source: fotolia

Illumination

Ga, In, SEE



Source: fotalia

Source: fotolia

Global concentration of copper and aluminium supply

- Electric cables
- Power lines
- Lithium ion batteries

Mineral raw material	Price Vola. 2012-2016	HHI 2014	GLR 2014	Share of the three largest producer countries
Aluminium (Bauxite) mine production	13.7	1,828	0.22	Australia, China, Brazil — 69 %
Aluminium smelter production		2,814	0.02	China, Russian Federation, Canada — 64 %
Copper mine production	15.1	1,301	0.40	Chile, China, USA — 48 %
Copper refined production		1,472	0.21	China, Chile, Japan — 53 %

HHI = Herfindahl-Hirschman Index; GLR = World Bank weighted global country risk

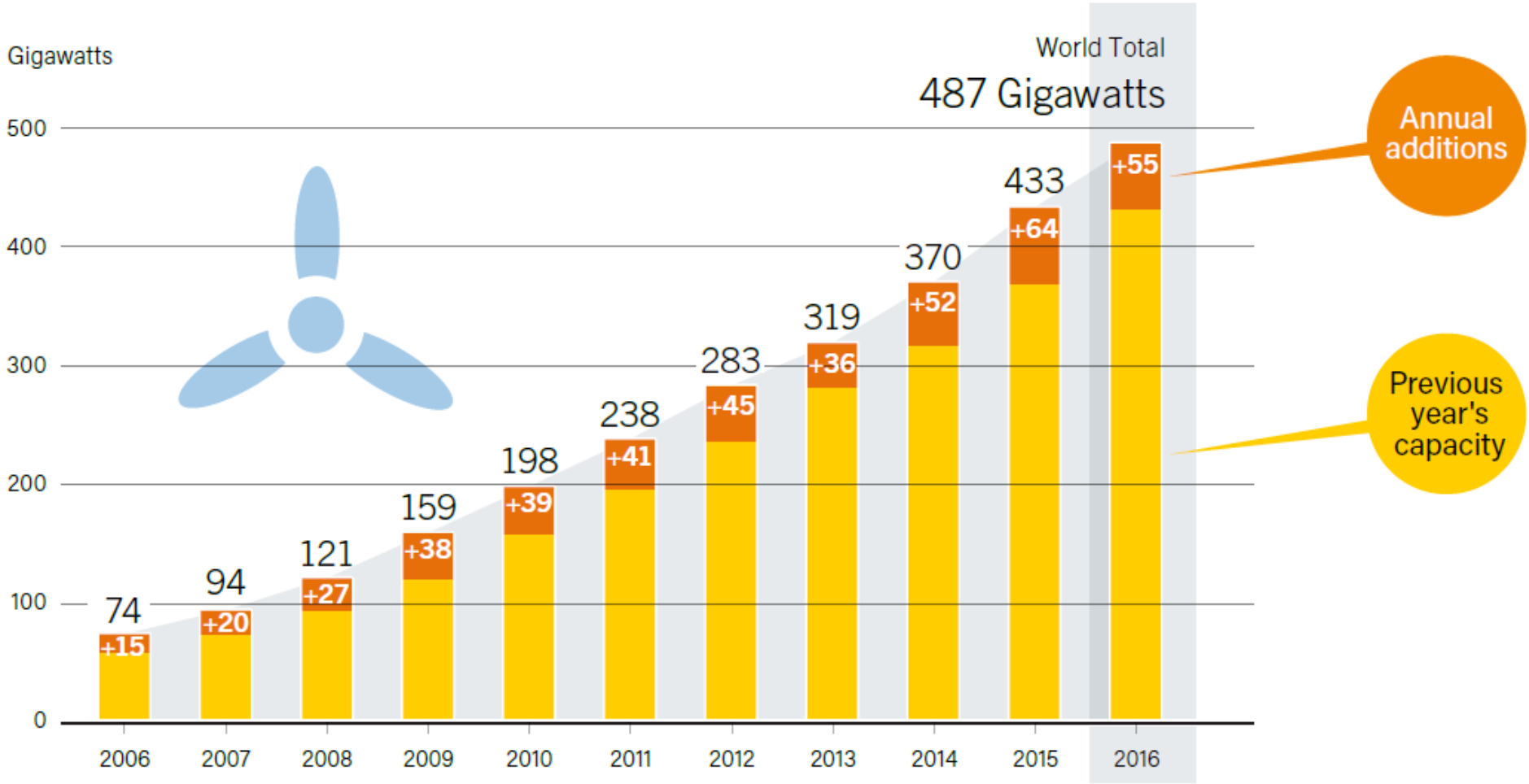
DERA (2016): DERA-Rohstoffliste 2016

Wind power

Cu, Nd, Dy, B

Source: fotolia

Globally installed wind electric power capacity, 2006-2016



Source: REN21

Global Concentration of rare earth element supply

- Raw materials for magnets in wind power plants

Mineral raw material	Price Vola. 2012-2016	HHI 2014	GLR 2014	Share of the three largest producer countries
Rare Earth E. mine production	11-51	7,941	–0.30	China 97 %, USA, Australia
Rare Earth E. refined production		8,826	–0.38	China 100 %, USA (incl. Estonia)[4], Russian Federation

HHI = Herfindahl-Hirschman Index; GLR = World Bank weighted global country risk

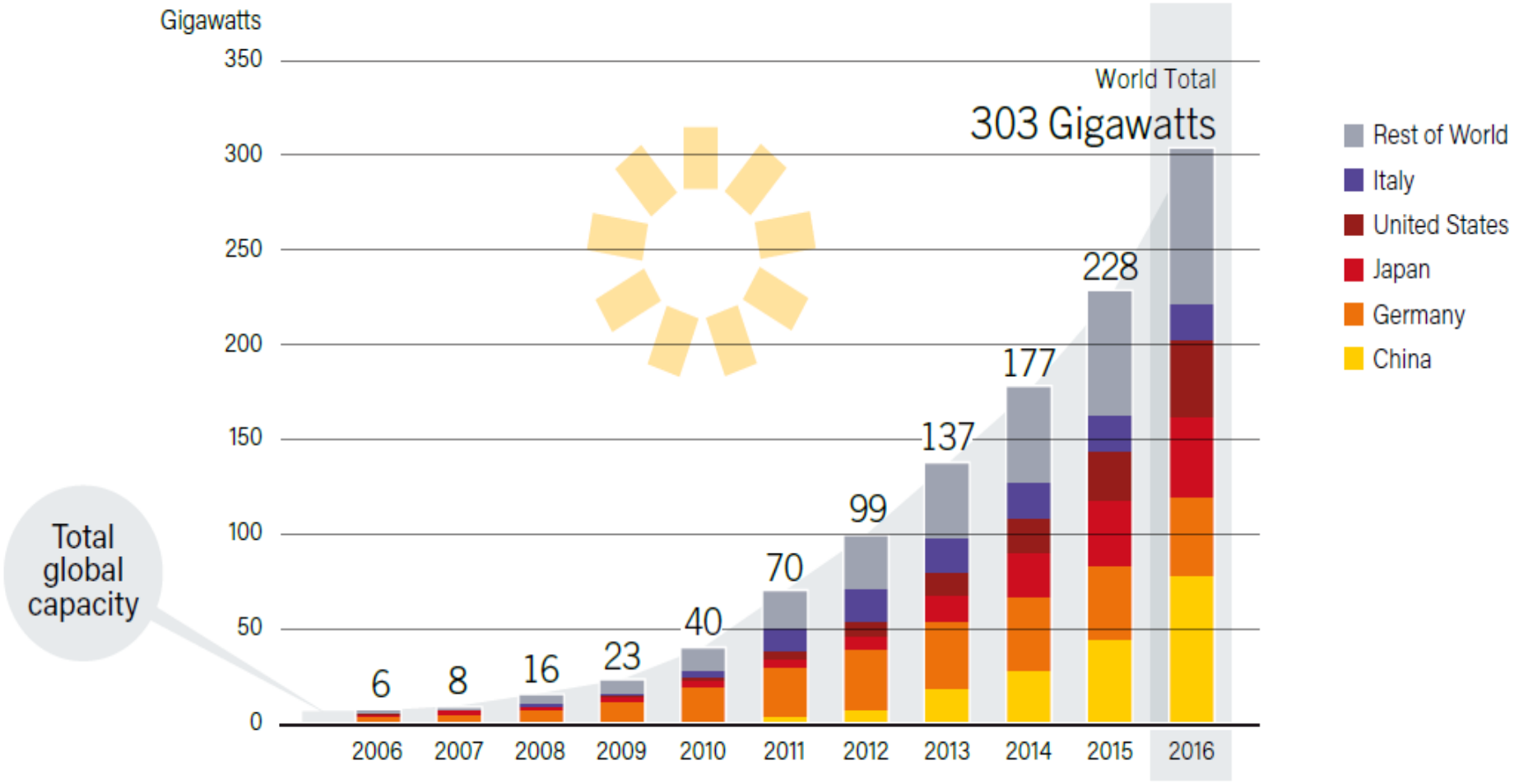
DERA (2016): DERA-Rohstoffliste 2016

Solar power

- Thin film cells of amorphous and crystall. Silicium
- Galliumarsenide cells (GaAs)
- Cadmiumtelluride cells (CdTe)
- CIS cells (Cu-In-Diselenide; Cu-In-Ga-Diselenide)

Quelle: fotalia

Globally installed solar photovoltaic electric power capacity, 2006-2016



Source: REN21

Global concentration of silicium, indium, selenium, cadmium, gallium supply

- Thin layer amorphous and crystalline silicium
- Gallium arsenide cells (GaAs)
- Cadmium tellurium cells (CdTe)
- CIS cells (copper-indium-diselenide; copper-indium-gallium-diselenide)

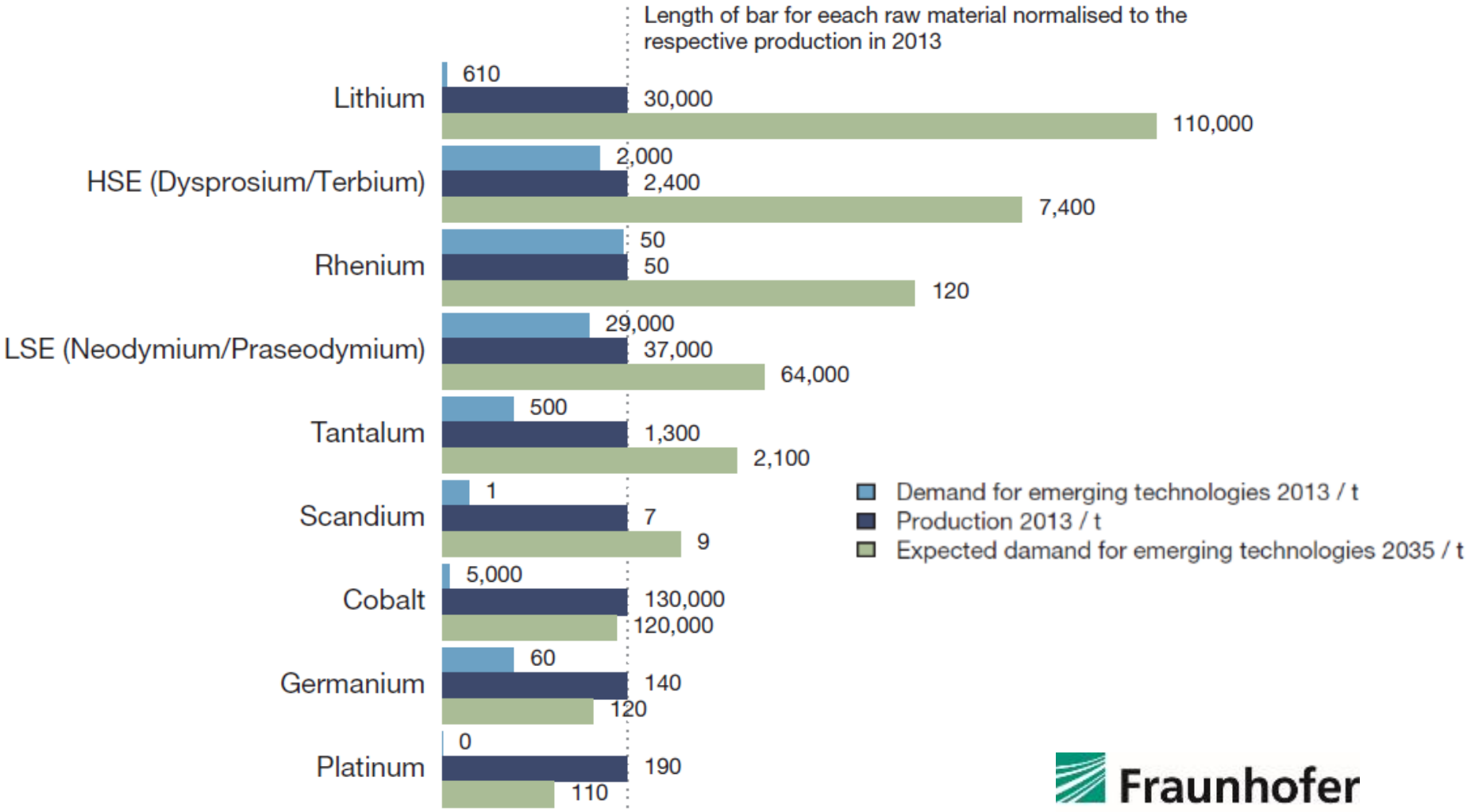
Mineral raw material	Price Vola. 2012-2016	HHI 2014	GLR 2014	Share of the three largest producer countries
Silicon refined production	8.7	4,096	0.04	China, Brazil, Norway — 78 %
Indium refined production	18.2	3,540	0.23	China, Rep. Korea, Japan — 82 %
Selenium refined production	38.2	1,592	0.60	China, Japan, USA — 61 %
Cadmium refined production	25.0	1,606	0.24	China, Rep. Korea, Japan — 60 %
Gallium refined production	15.5	6,726	–0.26	China, Germany, Kazachstan — 91 %

HHI = Herfindahl-Hirschman Index; GLR = World Bank weighted global country risk

Renewable energy technology	Relevant mineral raw materials (among others)
Solar photovoltaic energy	In, Ga, Se, Cd, Te, Cu, Si, Ag, Sn, Ge, Mo, steel (PV cells and construction)
Wind energy	Cu, REE (Dy, Nd, Pr, Y, Tb), Co, Mn, Cr, Mo, Ni, B, Ba, steel, quartz, kaolin, feldspar, sand and gravel, limestone (Magnets, generator, construction and rotor material)
Energy storage facilities	Li, Co, C, Ni, Mn, Al (lithium-ion batteries) V, Zn, Cr, steel (Vanadium redox batteries)
Electric grids and transmission, digitalization	Al, Cu, Ge, Si, steel, electronic elements (power lines, transformers, IT cables)

Mineral raw material for the energy transition (without e-mobility)	Category	Global production/ consumption 2013/2014	Estimated additional demand for renewable energy technologies (without EVs)	Szenario	Comment Buchholz, P. & Brandenburg, T, CIT, 2018
Copper	Refined production	22,470,000*	4,000,000-5,000,000*1	2035	Global economic growth and infrastructure extension
Aluminium	Refined production	53,290,000	n.d.	2025	Global economic growth and infrastructure extension
Silicon	Refined production	2,410,000	n.d.	n.d.	Thick layer and thin film solar PV
Indium	Refined production	834	198-218*3	2035	Thin film solar PV
Selenium	Refined production	3,700	173-240*3	2035	Thin film solar PV
Cadmium	Refined production	25,283	174-190*3	2035	Thin film solar PV
Gallium	Refined production	250*6	25-26*3	2035	Thin film solar PV
Tellurium	Refined production	450 to 550*6	198-218*3	2035	Thin film solar VP
Neodymium/praseo-dymium oxide	Consumption	28,900*5	4,000 to 18,000*3	2035*	Permanent magnets for wind turbines
Dysprosium/terbium oxide	Consumption	2,000*5	200 to 1,200*3	2035	Permanent magnets for wind turbines
Lithium (Li-content)	Mine production	31,801	5,000*4	2025	Stationary energy storage systems
Cobalt	Refined production	98,000	n.d.	n.d.	Stationary energy storage systems
Vanadium	Mine production	83,737	32,000*3	2035	Stationary energy storage systems

Mineral raw materials for key and future technologies towards 2035



Fraunhofer ISI

DERA Deutsche Rohstoffagentur
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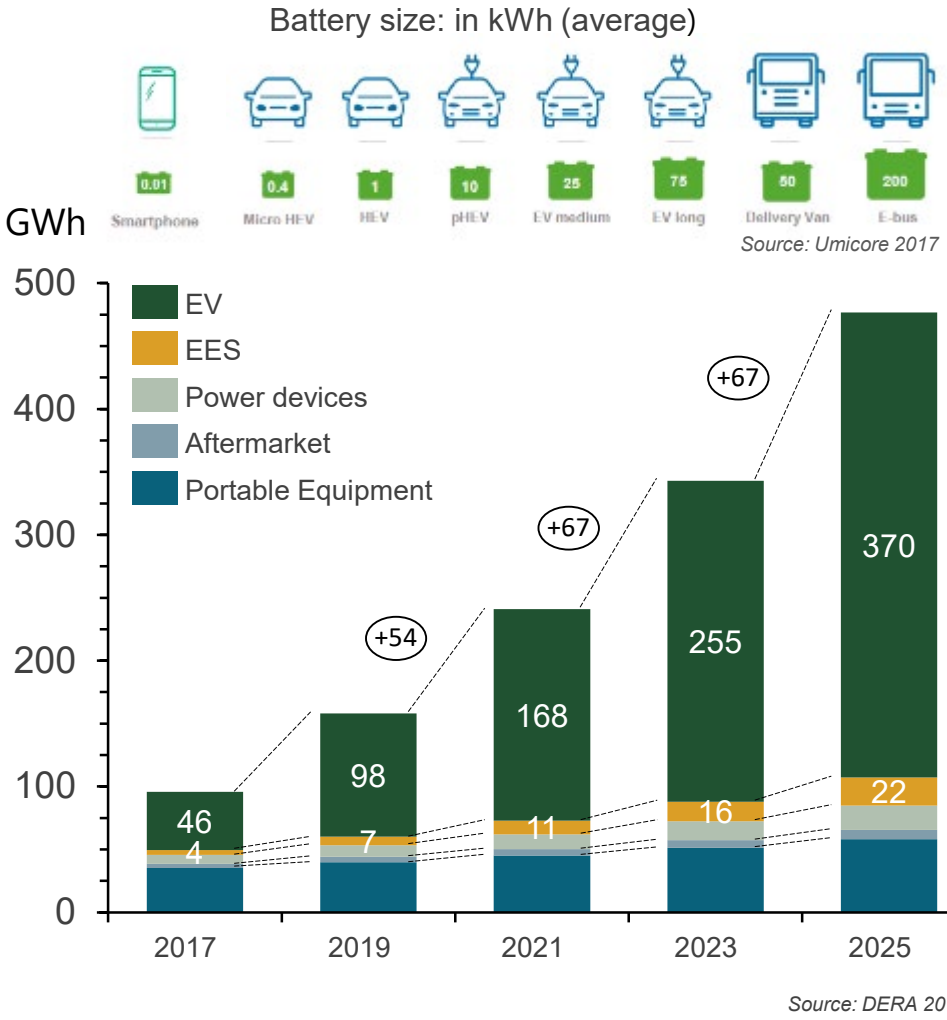
E-mobility

Li, Co, Ni, Mn, Graphite

Quelle: fotalia

Lithium-ion batteries – Growth potential up to 2025



DERA scenario
2025: ~10 Mio. EV, new registrations, 370 GWh

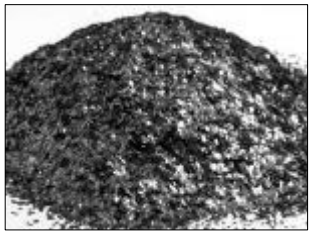
Increase of demand for:

Kobalt

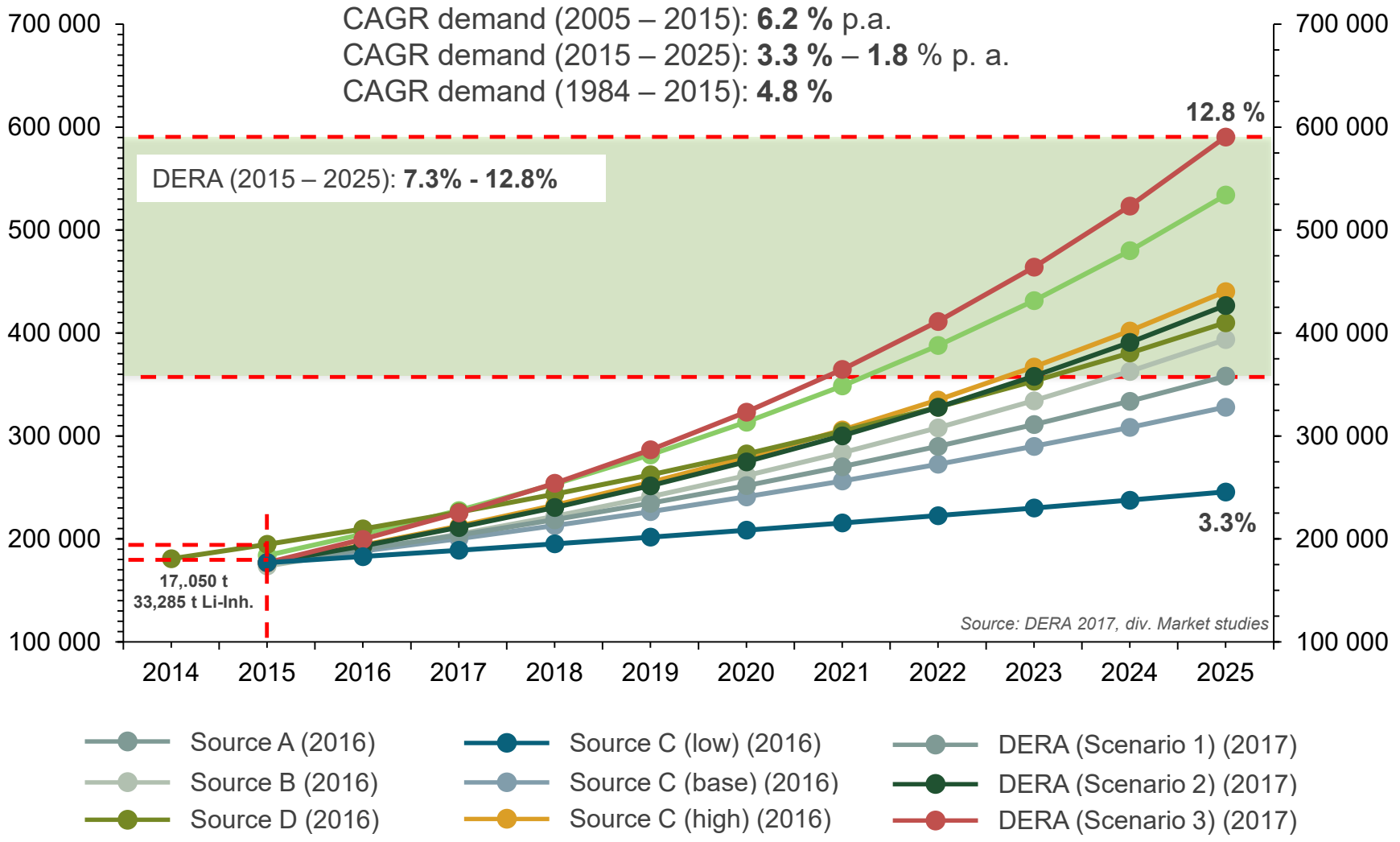
Lithium

Nickel

Graphit



Demand scenarios for lithium carbonate (2015 – 2025)



Global concentration of lithium, cobalt, vanadium supply

- Lithium ion batteries
- Vanadium redox flow batteries

Mineral raw material	Price Vola. 2012-2016	HHI 2014	GLR 2014	Share of the three largest producer countries
Lithium mine production	20.9	3,006	0.99	Australia, Chile, Argentina — 86 %
Cobalt mine production	18.0	3,651	–0.81	DR Congo, China, Canada — 71 %
Cobalt refined production		2,192	0.32	China, Finland, Belgium — 62 %
Vanadium mine production	25.6	3,847	–0.31	China, South Africa, Russian Federation — 97 %

HHI = Herfindahl-Hirschman Index; GLR = World Bank weighted global country risk

DERA (2016): DERA-Rohstoffliste 2016

Major mineral raw materials for lithium ion batteries

Cobalt

- **Mine production:** DR Congo 59%, China 7%, Canada 5%

Natural Graphite

- **Mine production:** China 70%, India 11%, Brazil 8%

Vanadium

- **Mine production:** Australia 39%, Chile 37%, Argentina 11%

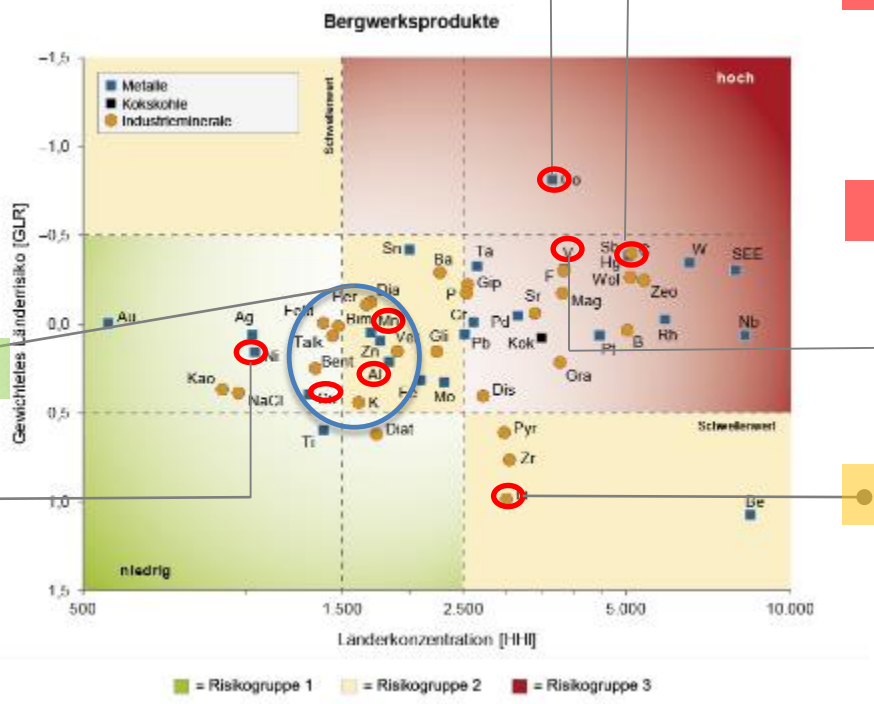
Copper, Aluminium,Manganese

Nickel

- **Mine production:** Philippines 21%, Russia 12%, Australia 11%

Lithium

- **Mine production:** China 53%, South Africa 25 %, Russian Federation 18 %



*For mineral raw materials of the **Risk Group 3** the probability is high for price and supply risks / market failure.*

DERA (2016): DERA-Rohstoffliste 2016

- Number 1 for global raw material consumption/production
- Decreasing growth rate for raw material consumption
- Sustainability and innovation instead of quantitative growth
- Environmentally safer raw material production / closures
- New import restrictions for Waste and scrap
- Controlled support for strategic industries
- Dissolution of the bancrupt Fanya Metal Exchange
- One Belt One Road Initiative will drive raw material demand
- Made in China 2025

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- Number 2 for global raw material consumption
- EU Battery Alliance and Action plan
- Raw Materials Initiative (RMI) + EIP Raw Mat.
- R&I EU funding in Horizon 2020
- EU Chemicals legislation
- EU Circular Economy Action plan and Monitoring Framework (2018)
- EU Supply Chain Due Diligence Regulation

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- Number 3 for global raw material consumption
- Presidential Executive Order on a federal strategy to ensure secure and reliable supplies of critical minerals (20.12.2017)
- Trade restrictions for Al and steel, possible trade war between USA-China-Europe
- Sanctions against RUSAL
- Import ban for Fe-Nd and Sm-Co magnets from China, Russia, Iran, North Korea

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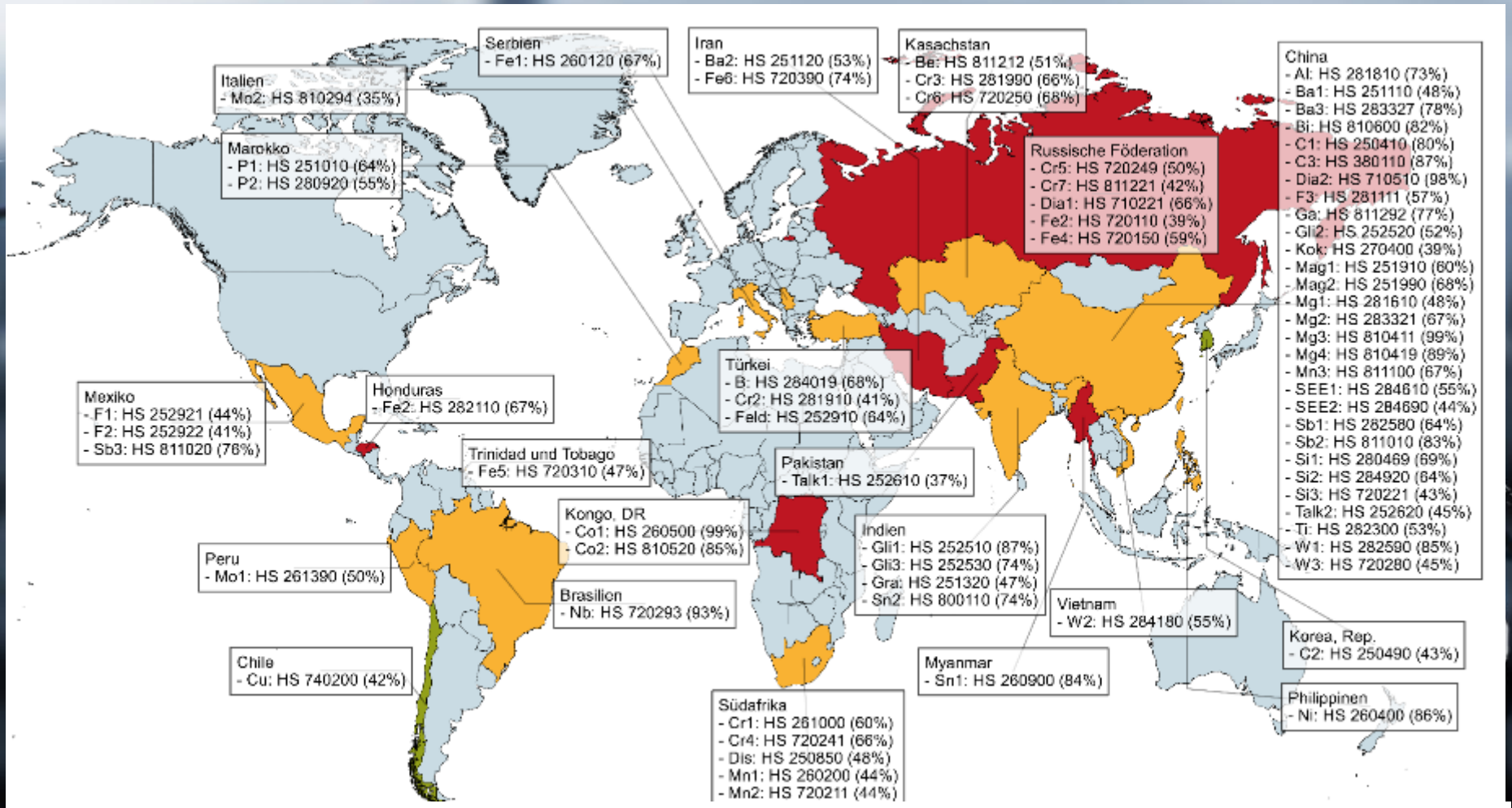
Market risks: possible trade war within times of rising oligopoles



Main exporting countries for mineral raw materials and intermediates, risk group 3

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Exploration budgets for global NE metal exploration 1996-2017

Inkl. Uran, Datenbasis SNL 2018

More sustainable supply; possible shortages through new environmental regulations

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Social aspects; possible supply shortages through social unrest, bad governance and mismanagement

©Fotolia.com

Resources and Energy

Century C19th C20th C21th C22th

Combustion
Radioactivity

Heat Radiation*, Wind Energy,
Hydro Energy, Magnetism**
Verbrennung, Radioaktivität

HHI_{min} = > 2.500

Renewable Energy ?
+ digital era
Si, Li, SEE, Co, In, Te, Cd, Ga, etc.

$HHI_{Erdöl}$ = 2.093

Fossil Fuel era
Oil, Gas, Coal, Atomic Energy

Wood-/Coal era

* Heat Radiation: Solar Energy, Geothermal Energy
** Magnetism, in combination with kinetic energy

1800 1900 2000 2100 Year