WORKING PAPER: ENERGY TRANSITION AND DEMAND FOR RAW MATERIALS

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INTRODUCTION

The Paris Agreement, adopted by 196 countries in December 2015, sets the ambitious target of limiting the global temperature rise to 2°C above pre-industrial levels. This will have a significant impact on the international energy sector, as a transition towards alternative and more sustainable forms of energy – renewables included – is set to become a priority for developed and developing economies alike. In line with the commitments made in Paris, the long-term objective of the European Commission is to transition Europe towards a low-carbon economy by 2050. The milestones outlined in the 2030 Framework for Climate and Energy include a decrease of total greenhouse gas (GHG) emissions by 40% relative to 1990 levels, and a renewable energy target of at least 27% of final energy consumption in the EU as a whole.[1] In the Netherlands, the Energy Agreement ("Energieakkoord") signed in 2013 aims to increase the share of renewable energy from 4.5% in 2013 to 15.9% in 2023, and to achieve an average energy efficiency saving of 1.5% annually. These measures are geared towards realizing a total energy savings objective of 100 PJ in 2020 and, by extension, towards meeting the goals outlined in the EU Energy Efficiency Directive.[2]

However, current activities are insufficient to meet the stated ambitions (**Figure 1**). According to the 2016 National Energy Outlook (NEV), neither the target of 14% renewable energy by 2020 nor the target of 100 PJ in additional energy saving by 2020 will be attained. Instead, the share of renewable energy is expected to reach 12.5% to 12.7% only. The 16% renewable energy target for 2023, however, is still considered to be within reach. This is largely thanks to development of offshore wind, small-scale renewable energy production, and projected reductions of total energy consumption.[3]

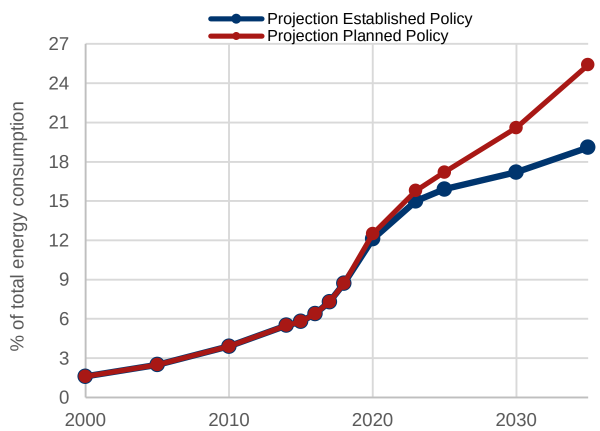

Figure 1: Development of renewable energy share between 2000 and 2035.[4]

Several projects to increase Dutch renewable output by 2020 have been planned. Although biomass is expected to remain the dominant source of renewable energy on a final energy consumption basis, the Energy Agreement focuses primarily on expanding the capacity of wind power (**Figure 2**).[5] While there has been little progress in the timely deployment of onshore wind energy – due to complex discussions in a number of provinces – the rollout of offshore wind energy is set to advance in the coming years. Three new offshore wind farms are currently under construction. Taken together, these are expected to produce an annual total of 3,500 MW by 2020.[6] Solar power is expected to grow less rapidly in comparison with wind energy. Although there are no large-scale government projects that invest in solar capacities, campaigns geared towards raising awareness about the technology combined with tax incentives have fostered significant growth in private-sector solar installations between 2000 and 2015.[7]

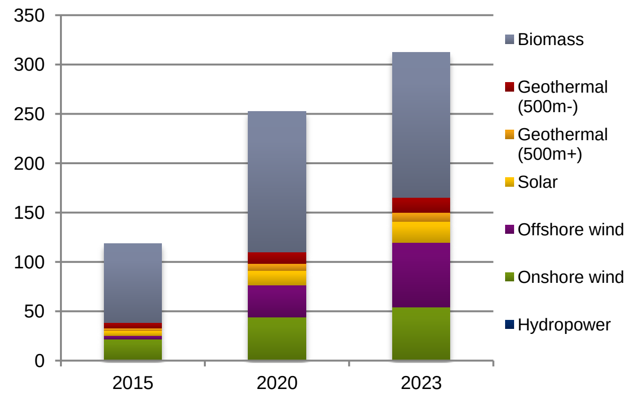

Figure 2: Gross final consumption of renewable energy by technology (in PJ).[8]

THE NEXUS BETWEEN RAW MATERIALS AND ENERGY TRANSITION

Power generation accounts for around 40% of global CO_2 emissions.[9] As a result, low-carbon technologies are set to play a fundamental role in the energy transition and are essential for achieving both EU and international climate and energy targets. Besides carbon capture and storage (CCS), nuclear fission and fusion energy, and fuel cell and hydrogen technologies, the EU's Strategic Energy Technology (SET) Plan identifies **four low-carbon technologies** as priority areas. These are wind, solar PV, electricity grid and bioenergy (biofuel).[10] In addition to power generation, the energy transition will also lead to an increase in the material demand in other sectors. One of the most important ones will be the **automotive sector**.

A wide range of different metals and minerals is required for the development and large-scale deployment of low-carbon technologies and, by extension, for meeting the ambitious goals stipulated in the Energy Agreement (**Figure 3**). In addition to demand for rare minerals, large-scale electrification will require the construction of new infrastructure. This will result in a substantial increase in demand for common materials such as copper, aluminum, lead, and steel. The linkages between the energy transition and international raw material chains thus merit closer attention.

Technology	Metals Requirement	Lifespan
Wind	Dysprosium, Manganese, Neodymium, Molybdenum, Nickel, Chromium, Copper, Concrete	25 years with normal maintenance and inspection.[11]
Solar PV	Tellurium, Indium, Tin, Silver, Gallium, Selenium, Cadmium, Copper, Lead, Silicon	Standard solar panel warranty is 25 years and the average life of a solar system is 30 years. The average lifespan of PV batteries is between 6 and 12 years.[12]
Electricity Grid	Copper, Lead	N/A
Biofuel	Ruthenium, Cobalt	N/A
Plug-in hybrids (PHEV) & electric vehicles (BEV)	Lithium and Cobalt (Batteries), Neodymium, Terbium, Dysprosium and Lanthanum (Permanent Magnets)	From 5 to 20 years. Tesla's vehicles come with an 8 years battery warranty.[13]

Figure 3: Metals requirements of the selected low-carbon technologies. Metals highlighted in red are included in the 2014 EU critical materials list.[14]

While the assembly of wind turbines mostly takes place abroad, the products of the solar and automotive industry are largely assembled within the Netherlands. Such homegrown technologies represent pathways to mitigate challenges associated with energy transition. They are good candidates to develop Dutch niche in circular economy planning because their local assembly makes potential regulation of metal use easier to enforce. Furthermore, they are affected by all problems associated with the procurement of critical materials. Addressing these issues may facilitate the adoption of policymaking initiatives, which will likely have a positive impact on Dutch energy transition as a whole.

CHALLENGES

Increasing Demand

Some of the raw materials needed for low-carbon technologies – such as dysprosium, chromium, cobalt, gallium, indium, neodymium, silicon metal and platinum group metals – are included in the EU's critical raw materials list from 2014, given their major economic importance for the Union and the fact that their supply is subject to a high level of risk.[15] Compared to fossil fuels, renewable technologies exhibit lower energy density and thus require a considerably larger volume of raw materials to operate effectively.[16] In addition, large-scale electrification – necessary due to a shift *away* from fossil fuels for heating – requires the construction of new infrastructure in developed and developing economies alike, and is thus likely to result in increased global demand for copper, aluminum and nickel. Population growth in the developing world means renewable technologies must power larger economies,[17] while a growing consumer demand for competing technologies (i.e. smartphones) means demand is not limited to the energy sector alone.[18] The interaction between such factors places considerable strain on the global supply chains of critical materials.

Uneven Geographical Distribution

The geographical distribution of mineral deposits is uneven. The largest suppliers of CRMs to the EU are developing countries or nations in transition – China, Brazil, Russia and South Africa, in particular.[19] Economic welfare in these countries tends to be associated with a high degree of dependence on the export of natural resources. Such a form of dependence incentivizes suppliers to resort to trade-restrictive measures and makes them vulnerable to the impact of demand fluctuations resulting from the adoption of circular economy models in importing countries.[20] Both of these phenomena may place further constraints on global mineral supply.[21] In addition, conducting business in the countries under discussion – China in particular – increases the risk of exposure to corporate espionage and trademark theft, which in turn erodes the competitiveness of European firms internationally.[22]

Scarcity Trap

Not all technologies are viable for long-term and large-scale energy production because the materials needed for their deployment are subject to limited supply. Supply may be limited by a handful of complementary factors, including bottlenecks in production and the economic feasibility of extraction. Supply is subject to changes over time: to avoid a scarcity trap *tomorrow*, technologies must correct for the projected availability of materials *today*. Planning around the concept of a scarcity trap thus requires a long-term, holistic understanding of what energy transition entails. Technologies whose construction sacrifices long-term material availability for immediate throughput may be considered non-viable as they foster dependence on resources, which may not be available in the future.

Energy and Mining

To meet the expected rise in demand, mining activities for these minerals need to be scaled up significantly. Increased mining will, however, consume additional energy: in 2013 alone, 10% of global energy consumption was due to the extraction and processing of mineral resources.[23] The introduction of renewable energy sources to power mines could help alleviate some of the environmental impact associated with mining operations. In the case of South Africa, for example, the installation of solar panels at mining sites helped reduce carbon emissions and demonstrated sustainable mining practices.[24] Another aspect that merits further consideration is that many of the minerals needed for the energy transition are not mined on their own, but are largely recovered as by-products during the extraction and refining of other metals. Indium, for example, is a byproduct of zinc processing operations; gallium is recovered from bauxite (aluminum) ore; selenium and tellurium occur in copper ores.[25] Because these by-products often constitute small fractions of the host metal, it will likely prove difficult to increase their supply – not to mention the significant amounts of waste such mining would generate.[26]

Environmental and Social Impact

To access rare and high-value commodities, unregulated, illegal and often unethical mining has been carried out. Given the ambiguity surrounding the supply chains of certain rare commodities, tracking the origins of mineral supplies is increasingly perceived as necessary. However, conflict-free sourcing is only a first step, and must be supplemented by measures that offset the potential environmental and social risks associated with mining. The environmental impact of mining activities is significant and includes issues such as water and soil contamination, habitat degradation, and air pollution. From a social perspective, the mining industry faces issues such as child and forced labor, and dangerous working conditions. To facilitate economic development in mining communities, policymakers and corporations alike need to adopt policies that enforce responsible mining standards. If the mitigation of environmental and societal impact is prioritized, sustainable supply of raw materials can be ensured in the long run.

Political Uncertainty

Energy transition in the Netherlands requires a sizeable and long-term private sector investment into low-carbon technologies. While a wind turbine can become profitable within four months of being brought online, solar panels take years.[27] Many raw materials are also subject to delayed returns on investment. Copper mines for example require over 10 years to become operational. This means that they should ideally be developed *today* to ensure an adequate supply *tomorrow*. Investments of such scale are characterized by a high degree of uncertainty. A similar dilemma has developed surrounding the economics of the circular economy, which require public financing to make the processing of small consumer electronics – in which the concentration of materials sought for extraction is extremely low – a profitable proposition. The political assurances necessary to mitigate such dilemmas are largely incompatible with the current free market ideology pursued by the Netherlands.

In light of these challenges, the following section outlines possible guidelines for future action.

POSSIBLE GUIDELINES FOR FUTURE ACTION

Ensure Commercial Viability of Renewable Technologies

- Cost reduction associated with the procurement of critical materials may be subject to practices which devastate the environment or employ forced labor. This undermines the competitiveness of companies that adhere to principles of corporate social responsibility. International adoption of standardized indices to measure corporate behavior in this area would help to ensure a level playing field. Such indices would ideally integrate factors such as environmental degradation and labor conditions into an energy input-output model.

- Opening new mines requires mining companies to make large investments of both time and capital. To do so, these ventures require stable long-term demand in order to be financially viable. Such demand cannot exist within the private sector without public sector commitment to the pursuit of energy transition in the long run. The degree of political commitment is currently limited, and needs to be stepped-up.

- There is a need for an increase in public funding for research on metals and minerals. At the moment, there is an overt focus on the bio sector. Focusing on one sector only – be it energy, food or construction – is not sufficient to solve the problem.

Limit Dependence on China

- China's low-cost mineral production impedes European corporations' ability to extract local resources in a competitive way, and thus fosters dependence on imports from China. Dutch authorities would be well served in heeding the private sector's appeal for the introduction of legislation that incentivizes mineral extraction initiatives within the European Union. Subsidization of costs related to procurement of machinery and workforce necessary to develop local mines would be welcomed by the private sector.

- China remains important for mineral production, but it would be beneficial to limit the country's role in assembly and engineering. State provision of financial incentives aimed at ensuring that both the technical know-how and employment opportunities remain in the Netherlands would be welcomed.

- China's niche in mineral extraction can be offset by the development of a European niche in circular economy planning. Doing so would reduce Europe's import dependence on China, and would require a comprehensive regulatory framework to function. Relocating assembly and engineering-related parts of the production process to the Netherlands could facilitate the development of such a niche. Doing so would also help ensure product compliance with eventual European regulatory standards.

Facilitate a Circular Economy

- There is a need for more investment into the development of technologies with a higher energy yield and into increasing the efficiency of existing systems.

- It would be helpful if controlling for the likelihood of material depletion became a standard practice in all policy making that awards funding to projects tackling energy transition.

- Large quantities of re-usable material remain 'captured' in retired products – such as old cellphones, for example – because end-users fail to submit them to processing facilities. Changes in societal behavior are needed to ensure the viability of the circular economy. These may also originate from within the private sector.

- An effective circular model may require the acceptance of less efficient renewable technologies if their outlook vis-à-vis recyclability is better than throughput-oriented alternatives.

- Planning for end-of-life reusability is key. Different technologies incorporate different metals in different ways. As each method of incorporation requires the development of a unique method of eventual extraction, legislation that pursues technology-based regulations fragments the recycling capability within the market. Legislative initiatives which focus on circular economy would see improved effectiveness if regulators approached the issue from a metal-based perspective. Standardization of extraction methods could ensure the financial viability of such procedures.

- Production of low-carbon technologies is spread out across Europe. Dutch windmills, for example, are partially produced in Denmark and assembled in the Netherlands. As a result, imported products are often incompatible with local recycling processes. This problem can be alleviated by circularity-related planning and regulation at the European level. Such regulation would ensure that when wind turbines approach the end of their life cycle that components produced in Denmark can be recycled in the Netherlands. If regulations at the European level cannot be achieved, developing such regulations at the national level would represent a positive first step.

Foster Awareness in Policymaking / Private Sector Action

- There is a need for greater awareness of the structural changes required to achieve the energy transition. Renewable electrification is the end goal, but many supplementary measures – such as the elimination of the construction sector's dependence on fossil fuels for example – are necessary. Dutch policymakers focus too strongly on the end result and pay insufficient attention to the strategic issues that need to be addressed in order to achieve it.

- Technological specialization varies across the private sector and different actors have a different assessment of issues that need to be tackled in relation to the energy transition. For example, as solar cells do not require cobalt to operate, manufacturers of solar cells are unlikely to have knowledge of issues associated with its procurement. The work of advisory bodies that are tasked with informing policymakers is problematized by such fragmentation of knowledge because it limits the potential for organized collective action. This problem is not unique to the private sector. Niche specializations have developed within academic and public sectors, too. Increased information sharing between and within the private, academic, and governmental sectors would help to produce a more holistic view of issues relating to energy transition. Such a holistic view would ideally prevent the public sector from focusing on technology-exclusive issues – the procurement of metals used in biofuel production, for example – and would facilitate the adoption of a more comprehensive policymaking framework.

- A campaign aimed at raising political awareness of the incremental changes required to achieve the energy transition through the presentation of a relatable multi-issue case study is needed. Examples of incremental change range from public education campaigns advocating energy saving to government subsidization of electric heaters. Energy transition is the final goal, but multi-sector reform is needed to realize it. The Dutch automotive and solar industries are suitable candidates for such a case study because they link negative local developments such as the unemployment of workers to macro-level challenges such as a sector-wide overreliance on Chinese production capabilities.

- Participation in current mechanisms to incentivize a level playing field largely takes the form of transparent corporate reporting on supply chain variables – labor conditions and the environmental impacts, for example – and is not mandatory. While stronger regulation at the international level would help, the building of a stronger consensus on the issue of corporate social responsibility within the private sector would go a long way.

Figure 4 (available on the following page) offers an overview of challenges and opportunities associated with selected raw materials required in low-carbon technologies.

	Technology	Derived From	Imported From	Challenges	Opportunities
Dy Nd **REE** Rare Earths Tb La	Wind	Secondary Bastnäsite / Mozanite	**NL** China **EU** China	**Chinese** monopoly on exports of REE's; increasing global demand for electronics; almost no recycling; social / environmental issues.	Diplomatic alignment with Germany to secure supply; invest / develop Iron Nitride magnets to replace in future.
24 **Cr** Chromium	Wind	Primary Chromite	**NL** China, Slovakia **EU** S. Africa, Turkey, India, Pakistan	No substitute in magnets; 95% of current reserves in **Kazakhstan**; also needed for stainless steel production.	EPCA EU–Kazahstan (leverage through dependence – EU is largest trade partner Kazakhstan).
24 **Co** Cobalt	Biofuel Electric Vehicles	Secondary Laterite / Magnamous	**NL** Uganda **EU** Russia	**DRC** is major global producer (child labour / war); competition from consumer electronics; demand for EV's projected to grow.	Invest in development of Li–Air technologies; improve trade relations with Australia.
31 **Ga** Gallium	Solar PV	Secondary Bauxite	**NL** Poland, Belgium **EU** Brazil, China, U.S., S. Korea, Canada, Japan, Russia, Hong Kong, Peru	Past export levies **China**, **Brazil** (political instability); key to LED lighting & smartphone displays; past incidence of toxic waste release.	Invest in development of Copper / Zinc–Sulphide thin–film solutions; rely on non thin–film technology; leverage EU trade relation with suppliers.
49 **In** Indium	Solar PV	Secondary Zinc Deposits	**NL** Poland, Belgium **EU** Brazil, China, U.S., S. Korea, Canada, Japan, Russia, Hong Kong, Peru	Past export levies & instances of heavy metals in water supply **China**, **Brazil** (political instability); key to LED lighting & smartphone displays.	Australian production may increase due to high Zinc occurrence; alternatives exist for use in competing technologies.
Ru Pt **PGM** Group Metals	Solar PV Energy Grid	Secondary Various	**NL / EU** Unknown **World**: S. Africa, Russia, Canada	Rapid global development means high projected demand; political instability **South Africa** (producer world).	High recycle rate from scrap –NL has high consumption of technologies which contain PGM's.
14 **Si** Silicon	Solar PV	Primary Silicate Mineral	**NL** Norway **EU** Norway, China, Brazil	Majority global reserves in **China**; substitutes (**Gallium**) not easier to procure; wide industrial applications.	Silicon can be recycled; minerals containing Silicon make up about 90% of the Earth's crust.
50 **Sn** Tin	Solar PV	Secondary Cassiterite	**NL** Indonesia, Bolivia, Thailand, Germany, U.K., Chile, Malaysia **EU** Indonesia, Peru, China, Bolivia, Thailand, Malaysia, U.S.	Licensing schemes / export levies **Indonesia**, **China** (political instability / resource nationalism) and links to onset of respiratory disease due to lack of regulation.	Tin used in many non–'function'–driven industries (aesthetics, etc); lead / Germanium can be substituted in Solar cells.
3 **Li** Lithium	Electric Vehicles	Secondary Brine / River Filtration	**NL / EU** Unknown **World**: Australia, Chile, Argentina	No viable alternatives in Li–Ion battery (projected growth); extraction from ocean water not yet commercially viable.	Lend NL expertise in extraction to nonproductive countries (i.e.: Bolivia); increase rate of recycling from consumer electronics.
28 **Ni** Nickel	Various	Secondary Laterite / Magnamous	**NL / EU** Unknown **World**: Canada, Australia, Norway, Russia	Wide applications in industry; **Philippines** recent closing of mines (environmental concern) may deprive **China** of key source.	EU does not consider Nickel critical (suppliers such as **Canada** are reliable); extensive deposits (though currently uneconomical) have been identified.
52 **Te** Tellurium	Solar PV	Secondary Copper Refinery	**NL / EU** Unknown **World**: Sweden, Canada, Russia, Japan	Substitutes associated with suboptimal performance; makes up only 0.001 ppm in Earth's Crust; Solar expected to grow globally.	Invest in development of Zinc / Copper–Phosphide solar cells to minimise solar dependence on Tellurium.

Figure 4: Challenges and opportunities associated with raw materials required in low-carbon technologies.[28]

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