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Strategic reserves of critical metals

Building block of a resilience-focused raw materials strategy

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The growing importance of rare metals as critical raw materials requires a new European resource policy. As part of a risk mitigation strategy, the development of strategic raw material reserves can work as a short-term supplement to the long-term restructuring of import channels. However, material diversity and technological complexity place high demands on reserve management. This article analyses the strategic potential of raw material stockpiling for Europe and gives recommendations for concrete instruments.

Key points

- **Strategic reserves of rare metals are an effective instrument** for reducing supply and price risks but require permanent market monitoring.
- **State support for decentralised stockpiling at company level** is the most appropriate mechanism for rapid implementation.
- **The complementary establishment of a public base reserve is sensible** but should be limited to the passive management of a selection of particularly critical metals.
- **The long-term key to greater resilience in raw material provision** is a restructuring of the European supply system.

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1 Background

The parallel occurrence of numerous external shock events in recent times has exposed the vulnerability of our fragmented international supply chains. The beginning of the chains, i.e. access to raw materials, is in particular focus, as the entire downstream value creation depends on it. Looking to the future, this applies especially to rare metals, which represent the transition to a post-fossil, digital age. Calls for a Europe-wide strategy for dealing with these critical raw materials have increased against this background. The EU Commission has announced a comprehensive legislative proposal with concrete instruments for next year.[1] In addition to the development of domestic production capacities, regulatory guidelines for the development of strategic reserves of rare metals such as lithium, rare earths, cobalt, etc. are to be part of this framework. In the medium term, such reserves could be the decisive key to increasing European resilience in the raw materials sector, especially in view of existing uncertainty about the feasibility and sustainability of European mining.

From a purely physical point of view, stockpiling rare metals poses fewer problems than in the case of oil and gas: they are solids, the respective demand quantities are significantly lower, and there are no complications due to seasonal demand patterns. From an economic perspective, however, new challenges arise due to the unpredictability of the markets: a high geographical concentration of supply meets a trend of strongly increasing global demand, with only very incomplete information about the existence and future exploitability of geological deposits. Therefore, specific strategies for stock management are needed that hedge against the different types of risks while avoiding undesirable market effects.

So far, there are only a few concrete ideas on the type and implementation of such stockpiling. The proposals debated in the literature and in the public sphere cover a broad spectrum of forms of intervention. As the mildest type of intervention, the introduction of a central information system for reserve management is proposed, while the reserves themselves are built up and managed independently by the member states or private companies. As an opposite extreme solution, the establishment of a kind of "metal bank" is being discussed, which would manage European reserves in a centralised manner and influence the global commodity markets with its transactions. In between, there is a broad spectrum of options.

This article examines the potentials and challenges of building up a strategic reserve of critical metals. It presents its own risk systematics and classifies the possible role of reserve holding as a building block of a European risk management in the field of raw material procurement. It analyses the economic rationale of commodity stockpiling in the light of the specificities of rare metals. It assesses different options for the institutional design of a European reserve management, including the important issues of the degree of centrality and the extent of powers. Finally, it makes recommendations for concrete instruments to rapidly build up European reserves.

[1] https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_22_5523

2 Stockpiling as part of a raw material strategy

2.1 Risks and instruments

The variety of future technologies that will shape our path into a digital, post-fossil age have one thing in common: they depend on the use of rare minerals (mostly metals) that are currently almost impossible to replace in production due to their physical-chemical properties. Rare earth metals, lithium and cobalt are the most prominent examples, but particularly rare metals such as gallium and germanium also fall into this category. From a European perspective, their high economic importance makes it particularly problematic that production and smelting are concentrated in a few non-European countries that represent strategic rivals or do not share environmental and social standards that are essential for the EU's self-image. First and foremost among these is China.[2] Turning away from fossil resources thus threatens to replace old dependencies with new, undesirable ones. The example of rare earth metals has demonstrated this in recent years. As an expression of a change in strategy, at the beginning of the 2000s China subjected its production of rare earth metals, once focused on the export business, to increasingly rigid export quotas, and from 2007 even imposed an export levy.[3] In 2010, a significant reduction in export quotas led to drastic jumps in export prices; in 2011, the average price increased by more than three times. The subsequent abandonment of the export quota policy then led to a significant easing of the price situation.[4] The dependence of Europe's hunger for raw materials on China has not noticeably decreased since that time.

The risks associated with rare metals are currently the subject of many analyses. Since its first Raw Materials Initiative in 2008[5], the European Union (EU) has regularly been conducting criticality assessments for raw materials. In 2011, a first list of raw materials classified as critical was published. In its current version from 2020, it includes 30 different raw materials. Criticality is derived empirically from a variety of indicators. In the currently applied methodology, it represents a mixture of relevance and risk measures: It combines measures of the economic importance of the materials with factors influencing the supply risk. The influencing factors considered are the degree of import dependence of the EU, global supply concentration, quality of governance in producing countries, degree of trade restrictions and recycling input rates. Raw materials are classified as critical if they exceed defined threshold values for both the economic importance sub-index and the supply risk sub-index.[6] Such an indicator system is helpful for prioritising a large selection of commodities, but as a risk management tool it needs to be expanded for several reasons. On the one hand, the risk assessment is limited to the supply risk, i.e. the risk of supply interruptions; other types of risk (price-related, environmental) are excluded. Secondly, the reduction of criticality to a yes/no decision is insufficient for many practical policy questions.

In the following, an own risk scheme for rare metals from the perspective of an importing country is presented. It distinguishes between three levels: Framework conditions, risk determinants, risk types. We identify three risk types: supply-related, price-related, ecological-social. The dimension of supply

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2 Wolf, A. (2022). Europe's position on raw materials of the future. **cepInput** Nr.11/2022.

3 Nicoletopoulos, V. (2014). European Policies on Critical Raw Materials, including REE. In Proceedings of the 1st European Rare Earth Resources Conference.

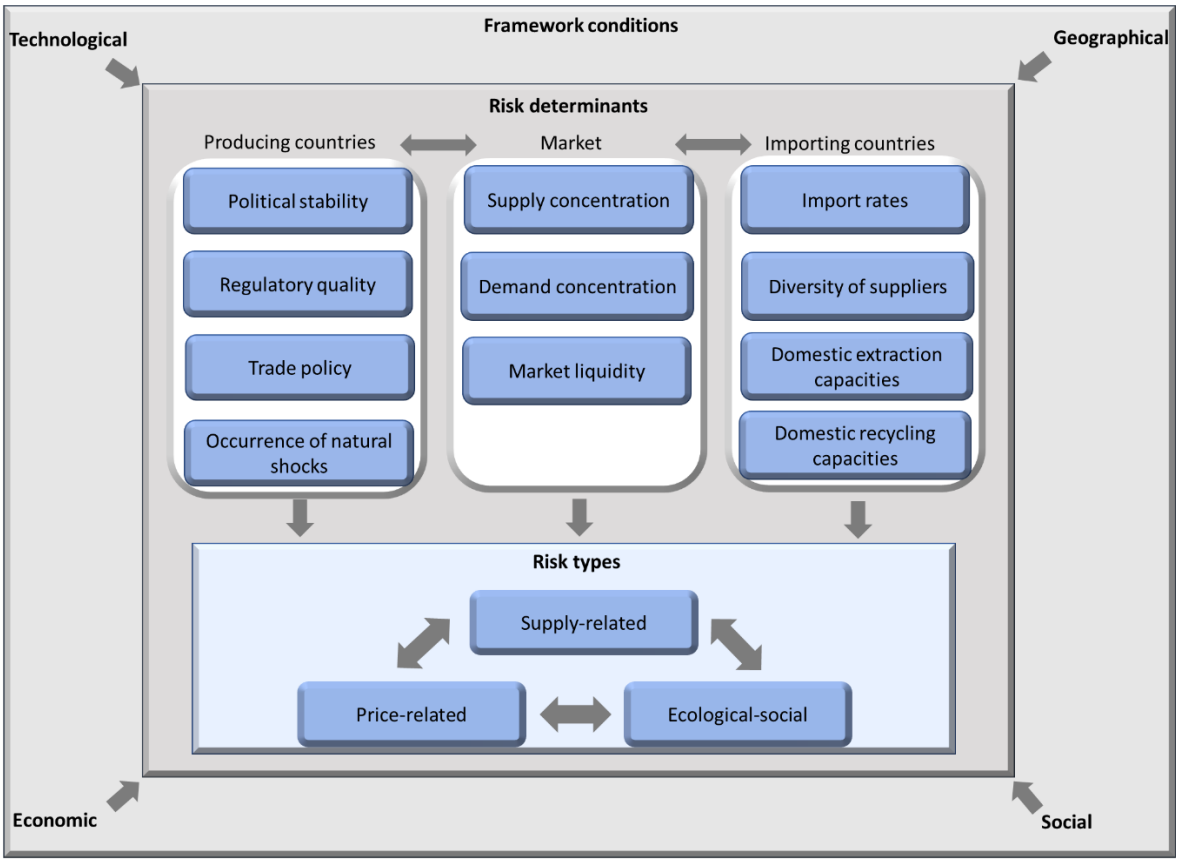
4 Mancheri, N. A. (2015). World trade in rare earths, Chinese export restrictions, and implications. Resources Policy, 46, 262-271.

5 European Commission (2008). The raw materials initiative — meeting our critical needs for growth and jobs in Europe. Communication from the Commission to the European Parliament and the Council. KOM(2008) 699.

6 European Commission (2020). Study on the EU's list of critical raw materials. Final Report, Brüssel.

security known from the EU criticality assessment is thus expanded by two dimensions. The price dimension captures the uncertainty in connection with price volatility, but also the risk of long-term price increases. The environmental-social dimension captures the risks associated with environmental damage and human rights violations in the producing countries. The dimensions are not considered independent but correspond to each other in many ways. For example, a growing supply risk should usually manifest itself in rising prices on the commodity markets; conversely, low prices in the long term can have a negative impact on the supply situation. Risks of an ecological-social nature, on the other hand, can partly be a consequence of price pressure, but in the long term can also affect the supply situation.

Figure 1: Risk scheme for rare metals



Source: own representation

This interplay of risks is influenced by a multitude of risk determinants. A distinction must be made between determinants at the level of the producing countries, the market and the importing countries. At the level of the producing countries, the legal situation with regard to the extraction, smelting and export of raw materials (trade policy) plays an important role, as does general political stability and the risk of "natural shocks" (natural disasters, pandemics, etc.). At the commodity market level, the market structure (number and relative size of suppliers and buyers) and liquidity are important factors. From the perspective of the importing country, the current procurement structure, the domestic production capacities, and the existing substitution possibilities are decisive determinants. Finally, the shape of the individual determinants is the result of an abundance of external framework conditions, which can be summarised in four dimensions: technological, economic, social and geographical. All these dimensions are not completely natural but are more or less influenced by political decisions from the present and the past.

From the perspective of an importing country, the question of the appropriate policy strategies to reduce or at least better manage existing risks arises. In its 2020 Action Plan for Critical Raw Materials, the EU mentioned the use of four different strategies.

Strategy 1: Promotion of domestic supply chains

Strategy 2: Diversification of imports

Strategy 3: Promotion of research in material substitution and efficiency

Strategy 4: Build-up of raw material reserves

The development of domestic production capacities in the raw materials sector requires extensive investments in tangible (capital) and intangible (know-how) goods and is time-consuming, also because it should not be limited to the raw materials extraction stage in view of Chinese market dominance in smelting.[7] Due to the unclear market reaction of the established producers, it harbours new price risks, and the occurrence of ecological risks in future mining regions cannot be ruled out at present. An alternative is the increased entry into secondary production (raw material recycling). Here too, however, significant capacities are not expected to be built up until after 2030. The diversification of imports starts on the demand side. Building up a portfolio of additional trading partners with long-term supply contracts could reduce risk factors on the producer side, but in many cases also requires long-term capacity building in the partner countries. Research funding could have a risk-reducing effect on the demand side, but here, too, hopes rest on the longer term. Building up raw material reserves is the only strategy that can in principle also be effective in the short term. At the same time, it is also the option that has been least present in the debate on commodity policy until now. In the following, the forms and objectives of this instrument are examined in more detail.

2.2 Types and goals of strategic reserves

By building up reserves, raw materials are temporarily withdrawn from their utilisation cycle. The most visible form is the build-up of stocks on the part of mining companies and the processing industry. The complex production chains for rare metals basically offer the possibility of storing them in the most diverse combinations and processing stages: as ore, in smelted form, in chemical compounds required for certain end applications (e.g. as a component of an alloy). Thinking beyond this, however, other stations along the entire value chain can also serve to hold reserves. This begins with the availability of the metals in the soil. In international raw material statistics, such geological deposits are referred to as "reserves" whose extraction would be economical under current conditions.[8] Depending on expectations about future market developments, it may be a rational strategy to refrain from mining today, even if it is economically viable to do so. The raw materials deliberately left in the ground represent a geological stock from which to draw when market conditions are more favourable. Stockpiling can also take place after the production stage. The rare metals contained in durable capital and consumer goods represent a raw material reserve that can be activated at the end of the products' useful life. The prerequisites are an efficient collection and sorting system, as well as technology-specific

[7] Seaman, J. (2019). Rare Earths and China: A Review of Changing Criticality in the New Economy. Policy Commons, Report.

[8] USGS (2020). Appendices – Mineral Commodity Summaries 2020. US Geological Survey. https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-appendixes.pdf

recycling capacities.[9] Under these conditions, the resource pool known as "urban mining" can fulfil similar functions as industrial resource stocks. Reserve management can also be differentiated according to whether it is decentralised (i.e. at the level of individual market participants) or centralised (coordinated by state institutions or private associations). Different models are also conceivable when dealing with reserve stocks. Reserve management can be limited to a purely passive management of stocks, but it can also use them as a basis for market intervention. We analyse the effects of individual models in section 4.

Different models can be based on different objectives. To the extent that reserves are not the outcome of economic misplanning (e.g. overestimation of market demand) but of a conscious decision, they are a form of intertemporal optimization. From the perspective of a commodity-importing country, reserve management can be primarily an instrument to counter the various forms of market risk discussed in the previous section. For example, stockpiling can be an attempt to protect against the risk of future supply disruptions along international supply chains. But it can also be done with a view to existing price risks. Here, a distinction must be made between short-term and long-term price uncertainty on the one hand, and between passive hedging and the desire to exert active influence on the other. In the short term, the focus may be on irregular price fluctuations on the commodity markets. Reserve holding can be an instrument for risk-averse players to individually hedge against price volatility. However, it can also stem from the motivation to have a price-stabilising effect on the markets themselves, if the inventory is dynamically adjusted to the respective price situation. In the long term, a positive trend in (real) commodity prices represents another risk. Here, too, stockpiling can either serve as a passive hedge against rising prices or be motivated by the hope of a long-term price-dampening effect. Finally, reserve stocks could be a means of coping with environmental and social risks if they are deliberately procured from regions with reliable environmental and social standards.

2.3 International experience

At present, only a few countries can be considered as possible role models for building up national reserves of critical raw materials. The following countries have official stocks of strategically important metals: the People's Republic of China, Japan, South Korea and the USA. In **China**, reserves are centrally managed by the National Food and Strategic Reserves Administration, the successor to the Strategic Reserve Bureau, which has been active in this field for a long time. In addition, several provinces operate their own programmes, which are, however, often limited in time. The instrument of reserve accumulation has been used repeatedly in the recent past for targeted market interventions in times of crisis, such as during the global financial crisis of 2008-09, the metal price crisis of 2012-13 and the demand fluctuations of 2015-16.[10] Due to the considerable volume of Chinese reserves, even rumours of such interventions can lead to turbulence on the international commodity markets.[11] This shows the market influence that inventories can have. Beyond that, however, the gain in knowledge from Chinese practice for Europe is small. As a raw materials exporter and the only country with vertically integrated value chains in the area of rare metals, China pursues a different rationale when it comes to stockpiling. In the past, purchases mainly served to reduce domestic surplus production in phases of weak global demand.

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9 Sander, K., Zimmermann, T., Gößling-Reisemann, S., Marscheider-Weidemann, F., Wilts, H., Schebeck, L., & Pehlken, A. (2017). Recycling potentials of strategic raw materials (ReStra). Final report. Umweltbundesamt, Dessau.

10 https://www.reuters.com/article/us-china-metals-stockpiles-ahome-idUKKBN22D56X

11 https://www.reuters.com/world/china/what-we-know-about-chinas-metals-reserves-release-2021-06-17/

More revealing are the examples of two countries which, like the EU, have recently become predominantly dependent on imports for critical raw materials: the USA and Japan. The **USA** have a National Defense Stockpile of raw materials since 1939, managed by the Defense Logistics Agency (DLA) - Strategic Materials. The reason for this was originally purely military: in view of the imminent threat of war, the US military was to be prepared for a national emergency situation; the liquidation of stocks was only planned in times of war. After World War II, the national stockpile of raw materials played an important role in the transition from a wartime to a peacetime economy, as surplus raw materials were transferred to the stockpile.[12] Stocks were now no longer procured from domestic sources alone, but also included raw material imports. Thus, the national stockpile became an instrument of risk hedging for internationally traded raw materials. The purpose, however, remained an exclusively military one. Under the impression of the first oil crisis, the National Security Study Memorandum of 1974 emphasised the necessity of building up domestic stocks of imported mineral raw materials for economic purposes as well.[13] The demand was reiterated by the US Congress in 1983 in a report on the raw materials situation.[14] However, the preferred political instrument during this period remained the subsidisation of domestic raw materials production. At the end of the 1980s, the end of the Cold War caused the raw materials issue to disappear from the strategic focus for the time being. The rise of China as a supplier of rare metals and the associated bankruptcy of US commodity companies did not initially lead to a political rethink. However, as China increasingly relied on export restrictions in commodity trade, the strategic relevance was rediscovered. The Obama administration's Critical Materials Strategy of 2010 advises against building up a national stockpile of rare metals for civilian purposes for cost and risk reasons, but at the same time suggests government support for private stockpiling.[15] The Trump administration's 2019 commodity strategy emphasises stockpiling as an important short-term measure to increase resilience in times of crisis.[16] There are signs that this has also led to practical consequences. For example, a significant increase in US imports of rare earth magnets was observed during the increase in trade tensions with China in 2019.[17] The increasing importance attached to the stockpiling of critical raw materials by US policy-makers has recently been confirmed by the Biden administration. In an Executive Order issued by the US President in 2021, a combination of public and private reserves of raw materials is described as an important buffer against import dependence and future shortages, and a strengthening of the National Defense Stockpile is announced.[18]

In **Japan**, security of supply of imported raw materials was proclaimed early on as a main goal of energy policy. The historical experience of material shortages during the Second World War was drastic for the resource-poor country and promoted a consistent policy response in the times of the oil crises. Since 1983, Japan has had a national rare metal preference strategy.[19] In the Strategic Energy Plan of 2014, the maintenance of rare metal storage facilities was identified as a key instrument for increasing

[12] Chappell, C. G., Gainer, R., & Guss, K. (1983). Defense National Stockpile Center: America's Stockpile: An Organizational History.

[13] Kissinger, H., & Scowcroft, B. (1974). Implications of Worldwide Population Growth for US Security and Overseas Interests. National Security Study Memorandum, 200.

[14] CBO (1983). Strategic and critical nonfuel minerals: problems and policy alternatives. Congress of the United States – Congressional Budget Office.

[15] USDE (2010). Critical Materials Strategy. US Department of Energy.

[16] USDC (2019). A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals. US Department of Commerce.

[17] Theodosopoulos, V. (2020). The Geopolitics of Supply: towards a new EU approach to the security of supply of critical raw materials? Institute for European Studies Policy Brief.

[18] Biden, J.R. (2021). Executive Order on the Designation to Exercise Authority Over the National Defense Stockpile. October 31, 2021. Presidential Actions.

[19] Ting, M. H., & Seaman, J. (2013). Rare earths: future elements of conflict in Asia?. Asian Studies Review, 37(2), 234-252

national resilience, in addition to the increased promotion of recycling activities.[20] The stocks serve both economic and military purposes and are actively managed by the Japan Oil, Gas and Metals National Cooperation.[21] Exact details of the nature and extent of the metals held in stock are confidential, including stocks of cobalt, gallium, iridium and vanadium.[22] Moreover, a few years ago Japan added another international pillar to its resource policy that sets the country apart from other importing nations. The National Energy Strategy of 2006 outlined a plan for strategic partnerships that explicitly uses development policy and international economic cooperation as instruments in the service of domestic resource security. Development aid, resource diplomacy and international investment promotion are to be coordinated with a view to the strategic goal of building stable international supply chains of critical raw materials beyond globally dominant suppliers.[23] A pro-active role of the government is explicitly envisaged: It should support Japanese companies in negotiations with foreign state-owned enterprises and also keep an eye on the regulatory development of the partner countries. The diplomatic crisis between Japan and China in 2010 and the associated fear of an export embargo by China in the area of rare earth metals have given this diversification strategy an additional boost.[24] Since then, Japan has entered into supply agreements and strategic alliances with countries such as Vietnam, Kazakhstan, Australia and India.[25] As a result, Japan was able to reduce the share of rare earth metals imports attributable to China from 93% in 2009 to 56% in 2021.[26] According to Japanese plans, this rate is to fall to below 50 % by 2025.[27]

3 The economics of strategic metal reserves

3.1 Economic principles

Since the oil crises of the 1970s/80s and the discussion on natural limits to economic growth initiated by the Club of Rome, the use of scarce resources has frequently been the subject of economic research. The problem of the optimal exploitation of a finite resource, as studied by Hotelling (1931), often serves as the basis for resource economic analyses. According to Hotelling's rule, the extraction of such a resource should be distributed over time such that the price increase of the resource corresponds to the return on alternative forms of investment on the market. In this way, for every tonne of resource left in the ground, non-extraction would yield exactly the same return as investments in the financial markets, so there would no longer be an incentive to adjust today's extraction rates upwards or downwards. [28] According to this reasoning, continuously decreasing extraction quantities and continuously increasing resource prices would be the logical consequence. There is no room for forms of stockpiling in such a concept: with a fixed extraction and price path, there would be no motivation for either suppliers or consumers to build up stocks as a precautionary measure. The price of stockpiling (lost interest on alternative investments) would be just as high as the expected price increase of the stored

[20] METI (2014). Strategic Energy Plan. Technical report. Ministry of Economy, Trade and Industry. http://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/4th_strategic_energy_plan.pdf
[21] https://www.jogmec.go.jp/english/metal/index.html
[22] Barteková, E., & Kemp, R. (2016). National strategies for securing a stable supply of rare earths in different world regions. Resources Policy, 49, 153-164.
[23] Amari, A. (2006). Japan: a new national energy strategy. Organisation for Economic Cooperation and Development. The OECD Observer, (258/259), 6.
[24] https://japan-forward.com/breaking-chinas-stranglehold-on-the-rare-earth-elements-supply-chain/
[25] see Barteková & Kemp (2016)
[26] UN Comtrade (2022). Angaben in Gewichtseinheiten. https://comtrade.un.org/data
[27] https://asia.nikkei.com/Politics/International-relations/Japan-to-pour-investment-into-non-China-rare-earth-projects
[28] Hotelling, H. (1931). The economics of exhaustible resources. Journal of political Economy, 39(2), 137-175.

resource. Even a short-term deviation from these paths due to singular events would not change this. If, for example, there is a temporary price collapse, this would create an incentive on the demand side to extend the purchase of resources beyond what is immediately needed. However, this would fail because the reaction of the suppliers in view of the higher expected return (stronger future price increase) would be to restrict current production, which in turn would stabilise prices.[29]

In reality, however, commodity price developments are usually far from the pattern of a continuous upward trend. Seemingly random fluctuations, spontaneous level shifts and sometimes unclear long-term trends are the predominant features of most commodity markets, especially in recent times. Economists have shown, however, that a relaxation of assumptions makes the Hotelling concept quite compatible with these phenomena. In particular, temporal changes in extraction costs and unpredictable fluctuations in commodity demand (business cycles, exogenous shocks) are put forward as possible explanations.[30] In a market concept modified in this way, stockpiling can be a rational and permanently practised strategy for risk hedging. The optimal level of stockpiling for a commodity-importing country depends on the forms of risk it is intended to hedge against and the alternative instruments available.

The economic literature has dealt with the role of resource stockpiling in the context of both supply and price risks. The classic ideal instrument for hedging against such risks would be a complete and fair insurance, i.e. a contract that in the event of a loss provides for full compensation for the damage incurred and premium payments in the amount of the ex ante expected loss.[31] In the commodities sector in particular, however, such a contract is inconceivable. To hedge the risk assumed, an insurance company would have to be able to balance the risk in its portfolio with other risks that are independent of it. However, events on the commodity markets are in many ways related to sectoral and macroeconomic developments, so that the degree of risk correlation would require a significantly higher premium.

Stockpiling, on the other hand, can be practised autonomously on the part of commodity users. Its fundamental disadvantage, however, is that it can never be completely risk-free. This is because reserves to hedge against the risk of future disruptions must already be built up today, and remain existent regardless of the occurrence of a disruptive event in the future. Since the build-up of reserves is always associated with costs in the form of foregone consumption or investment, the reserve holder will never be indifferent between the occurrence and non-occurrence of a disruptive event. However, the holding of reserves can reduce existing risks. This can be explained most intuitively with regard to supply risks that commodity-importing countries face on the international commodity markets. The risk of a future shortfall in the supply of raw materials due to unforeseeable events (natural disasters, pandemics, trade restrictions, etc.) can be reduced by bringing forward purchases. The amount of reserves built up will be determined by the cost of stockpiling and the degree of risk aversion, in addition to future commodity needs.

But how does stockpiling differ from the alternative precautionary strategy of boosting domestic resource extraction? McGuire's (2006) analysis provides interesting insights. He analyses a simple scenario of two countries that produce two goods and can trade with each other. Each country specialises

[29] Mason, C. F. (2011). On stockpiling natural resources. Resource and Energy Economics, 33(2), 398-409.
[30] Gaudet, G. (2007). Natural resource economics under the rule of Hotelling. Canadian Journal of Economics, 40(4), 1033-1059.
[31] Klein, R.W. (2014). A primer on the economics of insurance. Manuscript.

in the production and export of one of the two goods because of its natural advantages. One good can be a commodity, the other a manufactured good (produced without the use of the commodity in question). In the future, there is an (exogenous) risk that the commodity-exporting country will impose a trade embargo on the commodity-importing country. The commodity-importing country has two options to deal with this risk in the present: Build up commodity stocks through increased imports or shift domestic production towards the commodity sector (and thus away from the manufactured product). McGuire (2006) shows that the two strategies are fundamentally different in their effects. Relocation of production implies a loss of productivity for the commodity-importing country: labour and capital are withdrawn from the more productive industrial sector. Reserve accumulation through commodity imports, on the other hand, does not affect the production structure of the present, but is associated with a reduction in consumption. As a consequence, both strategies lead to a situation in which the commodity-importing country can mitigate its loss of commodities through domestic production in the event of an embargo, but has to live with a surplus of commodities (with lower consumption of the industrial commodity) otherwise. However, there is a difference between the strategies in the intensity of the effects. The build-up of reserves through imports can mitigate the raw material deficit of an embargo more strongly, but on the other hand causes a comparatively stronger raw material surplus if the embargo does not take effect. The reason is that the reserve build-up through imports can take place independently of the limited domestic production possibilities, and therefore leads to a stronger raw material transfer between the two states. **It follows that the more likely the occurrence of a supply disruption is, the more suitable is stockpiling as a hedging strategy.**[32]

The logic described also applies to other, unpredictable risk events of a non-political nature. It is also valid regardless of whether the relocation of production is a decentralised reaction of the private sector or the result of government intervention in the importing country (subsidisation, trade restriction). However, a limitation may be set by market price reactions. If there is evidence that the risk of a future supply shortfall is increasing, this could cause rising commodity prices in the present. Building up reserves would thus become more expensive as the risk increases. The crucial question is to what extent the respective commodity markets are able to correctly anticipate the likelihood of such extraordinary events and translate them into price signals.

The question of how well commodity markets process existing information about future risks is also central to the contribution of reserve holdings to the avoidance of price risks. If the efficient market hypothesis is valid, the current price level would have to reflect all market-relevant information, including estimates of the objective probabilities of future shock events.[33] Under these conditions, an importing country cannot hope to dampen long-term price increases or reduce price fluctuations by holding reserves. This is because all market-influencing events known today are already priced in, and future price developments are random from today's perspective. In this case, however, reserve management still has a useful function as a passive hedging instrument against future price volatility. If, on the other hand, the expectations of the market participants are subjectively different, or if irrational behaviour patterns can be observed, the current prices can be in contradiction to the fundamental data. Provided the importing country has sufficient market information, wise reserve management could be used here to exploit price anomalies in a targeted manner. However, it is difficult to predict

[32] McGuire, M. C. (2006). Uncertainty, risk aversion, and optimal defense against interruptions in supply. Defence and Peace Economics, 17(4), 287-309.

[33] Malkiel, B. G. (1989). Efficient market hypothesis. In Finance (pp. 127-134). Palgrave Macmillan, London.

how a reserve purchase (or its announcement) will affect the expectations of other market participants under these conditions.

The case is different if the market structure allows a form of direct strategic interaction between suppliers and demanders. For example, if a commodity market is characterised by the occurrence of market power among actors on both the supply and demand sides, stockpiling can become the object of a strategic game. Nichols & Zeckhauser (1977) highlight the consequences for the case of a supply cartel that faces one or more large importing countries as demanders. Building up reserves through increased imports today helps to reduce future dependence on the supplier cartel (and thus the risk of extortion). Present income is thus exchanged for the power to keep the import price at a low level in the future. For the reserve-creating institution, this is a costly strategy: it invests in an asset whose value is deliberately kept low. However, this can be offset by a gain in consumer surplus in the importing country.

The longer the time horizon, the more beneficial such a strategy becomes. The supplier cartel does not stop this approach, as it also profits: Part of its future profits is shifted to the present. In such a constellation, stockpiling is not simply a weapon against market power, but a mutually beneficial instrument for improved market coordination. The prerequisite is that individual players among the importing countries are large enough to be able to lead the way in building up price-stabilising reserves. If, on the other hand, the build-up is carried out in an uncoordinated manner by a large number of small importing countries, an incentive problem arises in the form of the well-known free-rider problem: individual countries profit from the price effect of the reserves held by other countries without having to bear the costs of holding the reserves themselves. Reserve holding thus becomes an international public good. A possible solution in this case would be buyer alliances, provided that a binding commitment can be ensured through sanctions.[34]

The qualitative economic arguments presented become particularly clear when considering reserves in the form of industrial storage. However, they apply equally to the other two forms of reserve management outlined in section 2.2. Both the holding of reserves in the ground and the expansion of recycling systems are associated with present costs and thus with consumption foregone. In both cases, capacities have to be created and maintained today in order to be available for production in the event of a crisis in the future. The return on these investments also depends on the future development of commodity prices. However, there can be differences between the forms in quantitative terms, especially in the level of physical costs of holding reserves and in the time span within which raw materials from the reserve can be made available in the event of a crisis. The environmental effects associated with reserve maintenance can also differ significantly in terms of type and extent.

3.2 Impacts of the specifics of rare metals

Much of the literature discussed above explicitly refers to the stockpiling of fossil energy resources. The question arises to what extent the arguments presented are also valid for critical raw materials in the form of rare metals. The raw materials currently identified as critical by the EU Commission differ in terms of their technical properties and supply chains. For all their heterogeneity, however, many of these materials share a number of characteristics that influence the economics of stockpiling. They exist as solids at natural temperatures. In terms of volumes, demand is significantly lower than for standard metals. Both of these characteristics facilitate storage and have a cost-reducing effect on the

[34] Nichols, A. L., & Zeckhauser, R. J. (1977). Stockpiling strategies and cartel prices. The Bell Journal of Economics, 66-96.

build-up of economically relevant stocks. In addition, the following characteristics are economically relevant.

1. Uncertainty about geological resources

For many critical raw materials, there is only very limited information on the extent, type and spatial distribution of the geological resources that can be exploited in the future. For metals that are physically particularly rare and only used in small quantities, such as gallium and germanium, there are not even official estimates of the global stock of economically exploitable deposits.[35] For many commodities, the official information on geographical location is limited to information on a few producing countries that are already active on a large scale today. There are several reasons for this. On the one hand, the raw materials are usually not directly available in the ground in their pure form (in the form of raw materials), but often as a small proportion of ores in terms of weight. The continuous development of extraction and smelting technologies leads to changes in the utilisation rates of existing deposits. Estimates of the quantities that can be profitably exploited are therefore particularly difficult. In view of the market situation, this leads to additional price uncertainty. For example, the discovery of large economically exploitable deposits in so far inactive regions can significantly influence the market architecture. Against this backdrop, stockpiling as an instrument to hedge against price fluctuations takes on additional significance.

2. Occurrence in complex combinations

The rare metals are often associated with other economically important minerals within the ores.[36] This complicates the economics of resource extraction. The extraction path will then not only depend on the price development on the markets for rare metals, but also on markets for the co-extracted minerals. In the case of the group of rare earth metals, the individual elements always occur in mixed form, whereby the mixing ratios can be very different. This technical complementarity creates a coordination problem on the commodity markets.[37] This is exacerbated by the fact that demand for the individual metals is subject to significant fluctuations for technological reasons.[38] Against this background, strategic reserves in the form of stockpiling can mitigate market imbalances over time and smooth out related price fluctuations.

3. Environmental risks in extraction and refinery

The mining and smelting of rare metals poses significant environmental risks. Unlike in the case of fossil resources, the focus here is usually not on greenhouse gas emissions, but on locally acting pollutants. Lithium deposits, for example, are often associated with arsenic.[39] When rare earth metals are mined, there is a risk of radioactive substances being released.[40] As the damage is local, its extent depends strongly on the local ecological conditions. There is also a lack of a standardised methodology

[35] USGS (2022). Mineral Commodity Summaries 2022.

[36] Marscheider-Weidemann, F.; Langkau, S.; Baur, S.-J.; Billaud, M.; Deubzer, O.; Eberling, E.; Erdmann, L.; Haendel, M.; Krail, M.; Loibl, A.; Maisel, F.; Marwede, M.; Neef, C.; Neuwirth, M.; Rostek, L.; Rückschloss, J.; Shirinzadeh, S.; Stijepic, D.; Tercero Espinoza, L.; Tippner, M. (2021). Rohstoffe für Zukunftstechnologien 2021. DERA Rohstoffinformationen 50, Berlin.

[37] Binnemans, K., & Jones, P. T. (2015). Rare earths and the balance problem. Journal of Sustainable Metallurgy, 1(1), 29-38.

[38] Bardi, U., Jakobi, R., & Hettiarachchi, H. (2016). Mineral resource depletion: a coming age of stockpiling?. BioPhysical Economics and Resource Quality, 1(1), 1-9.

[39] Kaunda, R. B. (2020). Potential environmental impacts of lithium mining. Journal of energy & natural resources law, 38(3), 237-244.

[40] Huang, X., Zhang, G., Pan, A., Chen, F., & Zheng, C. (2016). Protecting the environment and public health from rare earth mining. Earth's Future, 4(11), 532-535.

for quantifying damage. This makes it easier for producing countries to conceal the extent of damage and contributes to their incentive to keep environmental standards low in order to reduce costs. Building up strategic reserves in the form of raw material stocks can thus be counterproductive with regard to the ecological dimension of raw material risks under current supply conditions. Emissions would at least be brought forward, and with a view to future technological progress they would probably even be higher overall.

4. Diversity of material requirements

Rare metals such as lithium have far more than just one field of application. They are used in various industries and processes and fulfil different functions in them (e.g. as catalysts, alloying components, components of chips and batteries). Accordingly, the demands on quality and processing form that different products place on one and the same metal are heterogenous. For example, with regard to the use of the metal titanium for electrical applications, a significantly higher degree of purity is required than for its use as a component in the aerospace industry.[41] A central reserve stock that wants to ensure maximum independence along the supply chains would have to take these different needs into account. This can complicate the management of central stocks considerably. Developments in demand in individual sectors would have to be considered when compiling reserves, unless stockpiling is restricted to early processing stages from the outset.

5. Substitution risk due to technological progress

The example of rare earth metals also shows the sometimes rapid changes to which the usability of rare metals for certain processes is subject. For example, the rare earth metal europium was for a long time one of the most critical rare metals in terms of supply due to its use in the production of cold-beam lamps. The advent of LCDs and LED lamps then led to a significant drop in demand within a few years.[42] This creates an additional substitution risk with a view to reserve management. Stocks of rare metals that would no longer be needed due to technological progress would lose their function and at the same time suffer a loss in value.

6. Concentration on global markets

The markets for rare metals are characterised by a concentration on a few large, geographically focused suppliers. In particular, China's dominance in raw material extraction and smelting is a characteristic of the supply situation for many rare metals.[43] At the same time, at the level of processing stages for industrial end-use (e.g. permanent magnets, lithium-ion batteries), there is still a certain geographical concentration on the demand side in those regions that play a leading role in the dissemination of future technologies. There should therefore be scope for strategic interaction along the lines of Nichols & Zeckhauser (1977) (see section 3.1) in many cases. Coordinated stockpiling, whether organised by law or driven by private joint ventures, can thus become a strategic asset for importing countries to dampen long-term price developments in markets with a high degree of monopolisation.

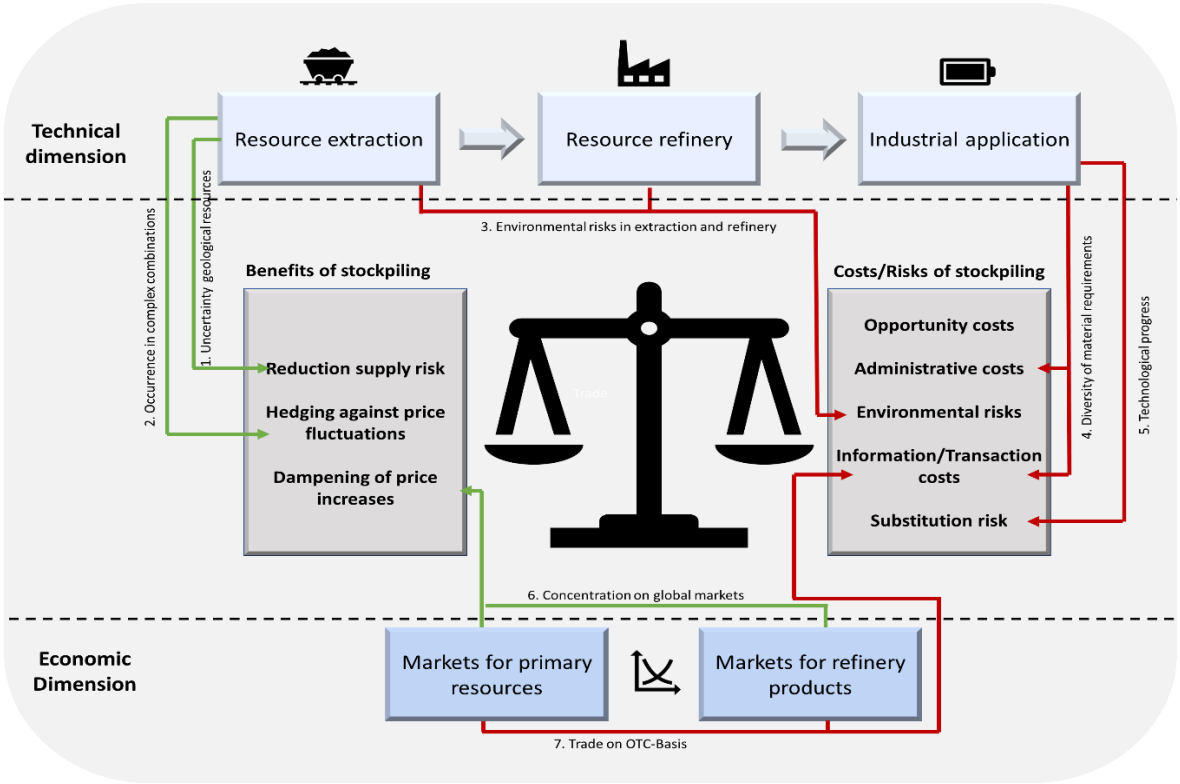
41 see Marscheider-Weidemann et al. (2021).
42 see. Binnemans & Jones (2015).
43 see Wolf (2022).

7. Trade on OTC-Basis

Unlike gas, oil and many standard metals, rare metals are not traded directly on commodity exchanges, but exclusively in the form of over-the-counter (OTC) contracts. The markets for rare metals can therefore not benefit from the central advantages of exchange trading: Transparency through standardisation, lower transaction costs, higher liquidity in trade.[44] Given the variety of chemical manifestations and processing stages in which rare metals can occur in trade, the lack of standardisation has a significant impact on the information and transaction costs of actors on the procurement side. This also applies to the process of stockpiling. At the same time, the absence of an exchange platform also means that there is less scope for purely speculative trading. Phenomena such as price bubbles generated or intensified by speculation are therefore less likely than on standardised markets. This eliminates a possible motive for hedging through stockpiling.

The discussed specifics influence the cost-benefit ratio of stockpiling, and thus its optimal level, in different ways (see Figure 2). However, they do not change its basic economic reasoning. Building up stocks of rare metals thus represents a fundamentally proven means of reducing supply risk and hedging against price fluctuations. Moreover, in the case of concentrated markets it can also be a strategic instrument for reducing the threat potential posed by dominant suppliers. At the same time, the significance of technology also shows that stockpiling requires continuous monitoring of markets, not only for the raw materials themselves, but along the entire value chain concerned.

Figure 2: Consequences of the specifics of rare metals



Source: own representation

[44] At least, reference prices are now published by various information platforms for almost all important rare metals. These refer to the trade of the metals in specific compounds and degrees of purity. DERA's price monitor provides a monthly overview.

4 Institutional design of reserve management

4.1 Implementation

The impact of strategic raw material reserves depends to a large extent on how their development and management is organized. In the case of reserves in the form of domestic mining and recycling capacities, long-term investment and extraction efforts are required in the first instance. Increased industrial stockpiling, on the other hand, can be implemented in the short term, but also raises a variety of design issues. First, it must be clarified to what extent a regulatory impetus is needed at all. The economic literature discussed in the previous section provides arguments in favor of autonomous stockpiling by companies. Individual stockpiling on the part of raw material consumers would thus be a possible reaction in two scenarios. In the first scenario, rising raw material extraction costs lead to sharply declining extraction volumes over time. Stockpiling in earlier periods may then represent an attempt to smooth consumption over time. Mason (2011) shows, however, that this can only be a rational strategy under very restrictive assumptions with regard to extraction technology and the level of the interest rate. Moreover, in the case of rare metals, the assumption of continuously rising extraction costs in the future is rather implausible due to the intensive research in the field of extraction technologies. A second scenario explains individual stockpiling as a reaction to the existence of unpredictable supply and demand fluctuations. These fluctuations trigger price volatility in commodity markets. Individual stockpiling allows risk-averse companies to engage in a form of real economic hedging against price volatility. This is because rising commodity prices increase the purchase costs of new inventories on the one hand, but also represent an increase in the value of old inventories on the other. The multifaceted role that external shocks can play in the markets for rare metals (see section 2.1) speaks in principle for such a motivation.

The question, however, is whether this market impulse is sufficient to achieve an economically optimal level of hedging via purely decentralized stockpiling. Since no figures are available on the overall level of current inventories, this cannot be clarified empirically. However, economic theory provides evidence that a purely decentralized buildup of stockpiles can lead to underprovision. This concerns both the functions of commodity storage to hedge against supply risks and to dampen long-term price developments. In both cases, there is a risk of free riding behaviour as discussed in the previous section. Companies based in commodity importing countries could use stockpiling to hedge each other against the risk of a supply shortfall by exporting countries. In the event of an actual shortfall, access via the internal market would still be ensured even without own warehouses. Regarding the price dampening effect of stockpiling, firms could benefit from the price impact of other firm's stockpiles, even without building up own reserves.

Another reason for suboptimal private stockpiling cited in the literature is the existence of economies of scale in inventory management. Accordingly, larger inventories only cause less than proportionally higher storage costs. This would imply that large centrally coordinated warehouses are economically more cost-efficient than decentralized warehousing at company level. This, too, cannot be empirically proven for rare metals at present. However, the existence of such economies of scale is plausible, since even small warehouses are likely to incur considerable fixed costs in the area of warehouse security and administration, given the high market value of low-weight inventories. Finally, the problem of disincentives through taxation is also pointed out. If a company makes extensive provisions through stockpiling, it can become a crisis winner in the event of a longer-term supply disruption: The value of its

inventories is likely to rise significantly. For reasons of general fairness, policymakers could feel compelled in such a situation to skim off the windfall profits by imposing a special levy. The knowledge of this danger, in turn, reduces the incentives for companies to build up inventories.[45]

Therefore, to the extent that stockpiling goes beyond pure hedging against price volatility, there are good reasons to assume a collective underprovision in the current situation of purely individual stock management. This raises the question of suitable policy instruments to address this undersupply. In principle, a variety of interventions can be envisaged, which differ in terms of centrality and degree of coordination. In the following, we distinguish four archetypal forms of regulation that together cover a broad spectrum of intervention types. Model 1 represents the conceivable maximum degree of centrality and coordination. The EU (or affiliated institutions) would have the task of creating a central stockpile of rare metals for the entirety of its member states. First, this would require the creation of competencies for the purchase and management of large resource stocks by the EU. Second, a transparent mechanism would have to be established to determine under which circumstances, based on which key and to which partners (to traders? to member states? directly to industrial companies?) stocks would be released.

Model 1: Implementation at EU level

Model 2: Implementation at level of member states, with strict guidelines by EU

Model 3: Implementation at level of member states, with loose coordination by EU

Model 4: Implementation by private companies, promoted with policy incentives

Models 2 and 3 also envisage the mandatory creation of public reserves in the EU area, but in delegated form at the level of the member states. In **Model 2**, the EU would set relatively narrow guidelines for the member states on the circumstances and extent to which they would be active in purchasing and distributing stocks. Such requirements should take into account differences in economic strength and sectoral structure between countries in order to reduce transaction costs and ensure rapid allocation of raw materials in the event of a crisis. **Model 3** also provides for an obligation to hold reserves at the member state level, but only in the form of a (needs-based) minimum stockpile of rare metals. The current requirements for holding oil stocks for emergencies could serve as a model for this. Under these, member states are required to maintain oil stocks at all times in an amount equal to either at least 90 days of daily average net imports or 61 days of daily average domestic consumption.[46] The existence of such minimum stocks would then have to be regularly documented to the EU. If, in addition, the member states are not free to distribute their reserves in the event of a crisis, but if - as in the case of the oil reserve directive - some form of internal EU coordination is initially prescribed, we can speak of a hybrid form of options 2 and 3.

Finally, **Model 4** continues to rely on purely decentralized storage at company level, but supplemented by regulatory incentives. Monetary incentives would be particularly useful in addressing the public-good problem of the hedging effect. By giving companies a direct financial benefit from the government for expanding their stockpiles, the positive externality for supply security of the general public

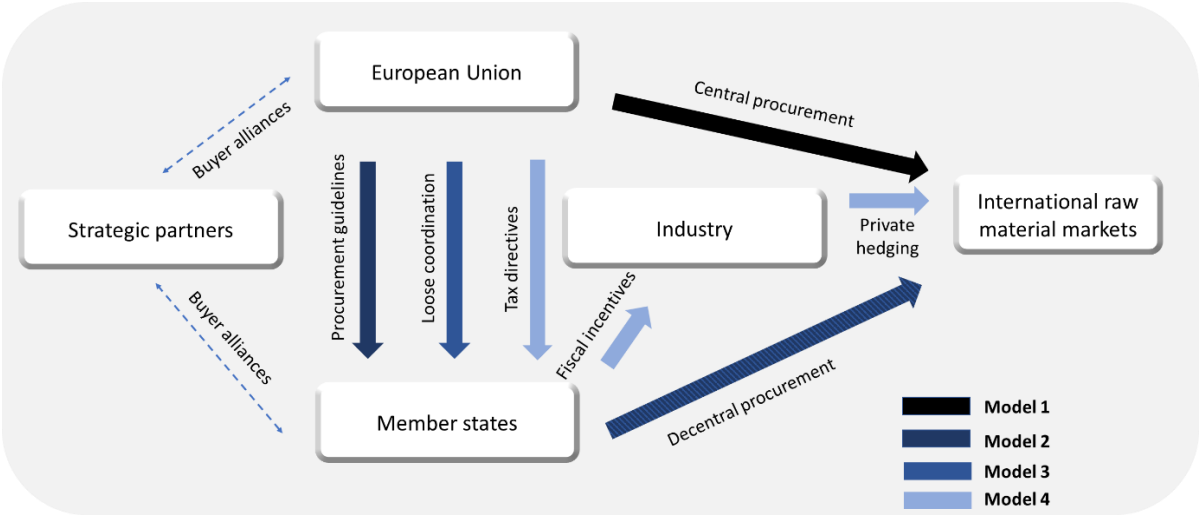
[45] see Nichols & Zeckhauser (1977).

[46] European Union (2009). Council directive 2009/119/EG imposing an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products

could be at least partially internalized. The challenge with such incentives is that they should precisely reward the build-up of additional reserves, and not simply the purchase of rare metals as such. Otherwise, there is a risk of consumption-side distortions in material use. Regarding the possible form of such incentives, considerations have existed since the time of the oil crises. At the level of tax policy, for example, incentives could be created by accelerating the depreciation of inventories (and thus reducing the profit tax burden). Investments in the build-up of inventories could also be promoted directly, for instance by reducing the cost of corresponding loans through guarantees. Incentives in the form of subsidies for private-sector joint ventures in the area of inventory investments are also conceivable.

All of the options discussed could be pursued beyond the EU area through the formation of international buyer alliances. The goal of such alliances with state institutions or companies from third countries could be to gain more leverage on commodity markets**,** and to exchange know-how in the field of risk management. The options are of a non-exclusive nature and could in principle be implemented in parallel, although the risk of crowding-out needs to be addressed (see below).

Figure 3: Overview on implementation options



Source: own representation

The greatest advantage of a centralized solution (**model 1**) is undoubtedly that it most consistently addresses the coordination problems inherent in stockpile development. The establishment of a central location at EU level solves the free-rider problem that exists between member states and EU companies. In this case, the transaction costs arising from the purchase and storage of reserves should also be lower than in the case of decentralized storage at the level of individual companies. Finally, a centralized purchase of large stocks of raw materials, especially in less competitive markets, would also offer the possibility of enforcing more favorable pricing conditions.

Table 1: Strength and weaknessess of different implementation options

Implementation option	Transaction costs	Danger of mis-planning	Free rider problems	Danger of crowding-out	Availability in crisis
1. Implementation at EU level	Low	High	No	High	Slow
2. Implementation at level of member states, with strict guidelines by EU	Medium	High	No	High	Medium
3. Implementation at level of member states, with loose coordination by EU	Medium	Medium	Yes	Medium	Medium
4. Implementation by private companies, promoted with policy incentives	High	Low	Depends	Low	Fast

Source: own representation

In contrast, the assessment of the administrative costs of operating raw material warehouses is ambiguous. On the one hand, centralized warehouses could better exploit economies of scale (e.g., related to security costs and space rent). On the other hand, the variety of configurations in which rare metals are required (see section 3.2) can pose major problems for the management of central warehouses. To the extent that stockpiling is not limited to the earliest process stages of raw materials, rational stockpile management would have to be based on demand forecasts for a wide range of industries and production processes. Other considerations clearly speak against an EU-based central solution. For example, the high demand for information, but also the fact that warehouse planners are not directly facing monetary consequences, harbors the danger of planning errors. Inefficiency in the type and scope of inventories could also be the result of a deliberate political strategy in such a centralized solution. For example, the EU could be trying to gain leverage over the member states in terms of industrial policy by means of a central stockpile that is excessively large from a risk point of view. This argues for permanent control of such instruments by the member states via the relevant councils of ministers.

Another risk of a centralized solution is the danger of crowding out private precautionary activity. By shielding domestic companies from market risks in the commodity sector, the EU reduces their incentive for risk reduction through their own initiative. This concerns their own stockpiling, but potentially also proactive measures to reduce the relevance of possible risk events, e.g. R&D investments in technical substitutes or own diversification activities in the international mining sector. Finally, another problem lies in the speed of stock availability in the event of a crisis. If there is an interruption in the supply of raw materials, it may be necessary to quickly supply raw material-intensive sectors to avoid devastating multiplier effects along value chains. This poses a major challenge for a centralized solution. If European reserve stocks are simply released into the market in such a case, industrial companies would have to pay high prices. It is also doubtful whether, in such a case, the raw materials would reach the most system-relevant players with priority. The alternative of a market-independent direct distribution to industrial companies at the European level (e.g. via auctions) would also be complex in terms of design.

Options 2 and 3 should mitigate the latter problem. In the event of a crisis, the member states could distribute their stocks directly to their companies according to their own criteria without having to go through EU institutions. Even with these models, however, there is a crowding-out risk with regard to private sector activities. In the case of the minimum reserve model (option 3), however, this risk is likely to be less acute, provided that the minimum requirements are only dimensioned for supply over a short period of time. In this case, there would be somewhat more flexibility than in the case of a

reserve policy strictly prescribed by the EU. This would also tend to reduce the risk of planning errors. On the other hand, looser requirements for member states could increase the risk of free-rider behavior. This is because companies in member states that only maintain the prescribed minimum level of reserves could also indirectly draw on the stocks of other EU countries via the internal market.

Option 4 is likely to entail higher overall transaction costs in the event of uncoordinated action. The decisive advantage here, however, is that reserve management remains in the hands of those who directly bear the economic risk of raw material dependence. The risk of planning errors should be comparatively low due to the market knowledge of the actors involved. Moreover, a significantly lower level of public information is required, since each company only has to plan its own technology-specific requirements. At the same time, availability in the event of a crisis is guaranteed the fastest. The existence of a free-rider problem will depend heavily on the design of monetary incentives. If the positive externality associated with the individual inventory buildup for the domestic market can be internalized, the danger of free-rider behavior will be contained. Special write-downs on inventories and loan guarantees for inventory investments are targeted means. However, their incentive effect is only temporary without further accompanying measures. To create incentives for companies to maintain stable reserve stocks in the longer term, direct support could also be provided for cooperative ventures in the reserve stockpiling of critical raw materials, for example by means of state subsidies for joint ventures. This would also have the advantage of reducing transaction costs in procurement and improving the possibilities of enforcing lower procurement prices.

4.2 Management and competencies

The build-up of raw material reserves generates fixed assets that could be managed actively or passively. In the case of purely decentralized stockpiling, management lies with the companies concerned. In the case of publicly mandated stockpiling, on the other hand, the management of stockpile resources should be the subject of explicit regulation. This includes, on the one hand, the question under which circumstances a (partial) liquidation of stockpiles is indicated and how this is to be carried out. On the other hand, it must be clearly regulated whether and in what form active management of inventories is permitted, irrespective of the occurrence of crisis situations. Three basic cases can be distinguished.

Model 1: Purely passive administration

Model 2: Passive administration with long-term adjustments to resource demand

Model 3: Active market engagement (Metal Bank)

The first two models are designed solely to provide sufficient raw materials in the event of a crisis. Stock management assumes a passive function vis-à-vis trading on the commodity markets. This does not rule out the possibility that the existence of reserves may also have a market-influencing function via repercussions on market demand (see section 3.1). However, the commodities held in stock are not actively traded. In **model 1**, inventory management would only include monitoring of legally stipulated inventory levels. **Model 2** would additionally provide for a continuous adjustment of stocks to consumption developments on the basis of ex ante defined rules. This corresponds to the design of the EU directive in the area of petroleum reserves. For rare metals as raw materials, however, longer-term adjustment periods would be appropriate.

Model 3 includes not only scheduled inventory adjustments but also an active role for the administrating institution on the commodity markets. It is given the authority to make targeted purchases or sales of raw materials on the market depending on the market situation (supply, price development), and thus to dynamically adjust inventories to market developments. The motivation for such market interventions can be, on the one hand, to constantly adjust the commodity portfolio to changes in the risk assessment. On the other hand, they can also represent an attempt to use recurring price fluctuations for value enhancement, by limiting purchases to low-price phases and sales to high-price phases. Finally, extensive forms of intervention may also be motivated by the desire for price stabilization. A distinction would have to be made whether such market interventions may be carried out on a discretionary basis or whether they are tied by law to specific conditions (e.g. minimum markups of prices over a certain period of time).

Against this background, Bardi et al. (2017) have brought the concept of a public "metal bank" into play. It envisages not only the reserve storage of rare metals but also their active trading for the purpose of both risk hedging and profit generation. This trade would not have to include the physical transfer of the metals, but could be done through the issuance of certificates by the metal bank, which would be fully covered by the quantities in stock. The idea is to create own parallel markets by trading with certificates, which, however, would be anchored in the real availability and thus the events on the international commodity markets. The aim of this approach is to create a closed circuit of investors in order to limit the influence of speculation on commodity prices and to achieve a price-smoothing effect on the commodity markets.[47] The scope of competence of such a bank evokes associations with the European Central Bank (ECB).

From a transaction cost perspective, the concept of a market-intervening, public commodity bank would be relatively efficient to implement for rare metals. The lower market volume compared to bulk commodities would limit the amount of strategic trading necessary for a market-influencing effect. Physical trading costs could also be avoided via a certificate solution. However, the general reservation against central reserve management applies even more strongly to this model. The decision-makers of a metal bank are not directly affected by the long-term consequences of a physical shortage of raw materials. They will be tempted to focus their activities on immediately visible successes. This could include, above all, the achievement of short-term profits on the commodity markets.

The focus on such a target may conflict with the fundamental principle of reserve holding, the precaution against supply risks. For example, in the short term, sharply rising prices could encourage a metal bank to sell stocks. However, if the price increases are the consequence of an increased supply risk, this would be exactly the opposite of what would be expected from responsible reserve management in such a situation. Even the concept of trading stocks only indirectly in the form of certificates does not change this. This is because their value is only derived from the expectant right to the resource. And the tendency to redeem this right grows with increasing supply risk. This shows how much a comparison with the ECB is misleading: A metal bank would have no possibility to create its own market supply, but would always remain dependent on the global availability of raw materials. The attempt to prevent unintentional risk-promoting market behavior by imposing tight intervention rules is also not very promising. This is because the same type of intervention could be understood quite differently by the other market players and trigger unexpected market reactions. It is difficult to cover the diversity

[47] Bardi, U., Jakobi, R., & Hettiarachchi, H. (2017). The Metal Bank: A Management Model for Rare Mineral Resources in a Circular Economy.

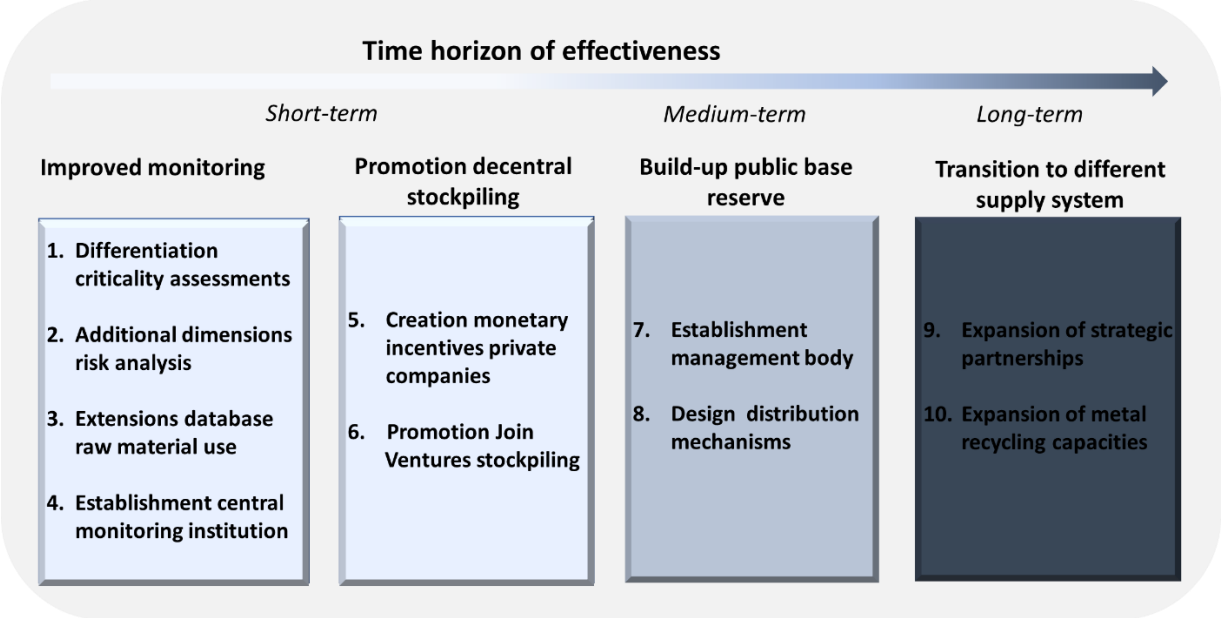
of such reactions with a set of rules. Finally, an institutional conflict with the ECB's sphere of interest is also conceivable. To the extent that a metal bank can actually intervene in price formation on the international commodity markets, it would have an indirect influence on macroeconomic inflation rates that should not be underestimated.

Private actors also face potential conflicts between the different types of risk when it comes to pro-active stock trading. However, the trade-off should work better, as they are primarily affected by the risks themselves and their specific market knowledge should be based on their own experience. For centrally managed reserves, on the other hand, specifications in the sense of **model 2** would be the most sensible management principle. **The demand-driven approach not only avoids the incalculable risks of market intervention, but also sets lower information requirements. Price developments and risk profiles would not have to be permanently monitored by the administrating institution. Reserve planning could be limited to maintaining a basic stock of rare metals, which would be adjusted to overall economic development in the long-term.**

5 Political recommendations

A number of recommendations to the European level that can be implemented in the short term can be derived from the previous analyses on the economic viability and practical design of strategic reserves. These can be divided into four categories based on the timing of their effectiveness.

Figure 4: Ten fields of political action



Source: own representation

5.1 Improvement of risk monitoring

Improving the information base is an important first step toward more active management of commodity-related supply chain risks. Risk situations should be assessed in a differentiated manner on the basis of reliable data, and monitoring should be consolidated.

Recommendation 1: Differentiation of criticality assessments

The criticality methodology developed by the EU Commission for determining its list of critical raw materials provides a scientifically sound basis for the relevance and risk assessment of various raw materials. However, for the planning of key raw material reserves, the current methodology would need to be further differentiated. First and foremost, the final criticality assessment should no longer consist solely of a yes/no decision, but should give way to a categorical scale assessment (e.g. in the form of a "risk barometer"). In addition, the final assessment should also consistently differentiate between the stages of raw material extraction and processing, as was already done in the last report by means of a double-stage assessment.[48] In this way, the current level of criticality - and its location in the value chains - can be better weighed between the individual raw materials. This would be particularly important for the establishment of a central raw material reserve, as such a reserve should be limited to raw materials classified as particularly critical. For the same reason, it would also be advisable to update the criticality assessment more frequently than in the current three-year cycle.

Recommendation 2: Additional dimensions for the risk analysis

The methodology used so far by the EU in criticality assessment is limited to supply risks. Risks of a price-related and environmental-social nature are not explicitly included in the index calculations. However, our analyses have made it clear that the assessment of the suitability of instruments such as strategic reserves can vary widely depending on the risk dimension considered. Also, the neglect of the ecological-social dimension is not in line with the EU principles currently manifested in the Green Deal. Against this background, the extension to a multidimensional risk assessment is advisable. The collection of indicators gathered by the Joint Research Centre (JRC) in the *Raw Materials Information System*[49] can serve as a basis, which should be expanded by market-related data.

Recommendation 3: Extension of the database on raw material use

For the relevance assessment of rare metals, more specific empirical data on their use in European industries would be helpful. The assessment of economic relevance in the current EU criticality methodology is based on a pre-selection of technological applications and their case-by-case allocation to individual economic sectors (according to NACE classification).[50] Existing forecast studies mostly focus on the use for specific future technologies without quantifying the overall demand. For a more robust assessment, the development of EU-wide statistics on the actual use of different rare metals in NACE industries would be helpful. The existing model estimates released by Eurostat in the *Material Flow Accounts*[51] should be expanded by a sectoral dimension. In this way, industry trends in material productivity and substitution could be assessed at an early stage in terms of their relevance for reserve maintenance and other commodity policy strategies.

Recommendation 4: Establishment of a central monitoring institution

For the continuous evaluation of market information in the area of rare metals and its translation into political recommendations for action, the creation of an independent monitoring body as a separate EU organizational unit would be advisable. This unit could also coordinate a permanent raw materials policy dialog between the EU Commission, member states and European industry. Moreover, they could act as a point of contact for industry on questions of raw materials-related risk management. In

[48] see European Commission (2020).
[49] Joint Research Centre (2022). EU Science Hub - Raw Materials Information System.
[50] see European Commission (2020).
[51] https://ec.europa.eu/eurostat/web/environment/material-flows-and-resource-productivity

connection with the build-up of central raw material reserves, its sphere of competence could also include the continuous review of specifications on the type and size of stocks held (see Section 5.3).

5.2 5.2 Promotion of private stockpiling

For the reasons discussed in section 4.1, decentralized stockpiling of rare metals at company level is the most effective and efficient form of building up strategic raw material reserves in the short term. However, this requires stronger incentives from policymakers. In each case, it is important that these incentives are as neutral as possible in terms of raw materials so as not to distort the production and research decisions of companies.

Recommendation 5: Creation of monetary incentives for private companies

Increased monetary incentives for industrial companies to stockpile rare metals could help to combat the "public goods" problem of supply risk within the EU. Concrete instruments could be tax incentives in the form of special depreciation on inventories, or government guarantees to secure more favorable loans for financing stockpiling investments. The positive external effect of individual stockpiling on supply security of the European industry (and, depending on the market situation, possibly also on the prospect of long-term price moderation) would thus be internalized to some extent.

Recommendation 6: Promotion of Joint Ventures in the field of stockpiling

The instruments mentioned in recommendation 5 are focused on promoting the build-up of inventories. In order for these instruments to have a risk-reducing effect, however, it would also have to be ensured that companies have sufficient incentives to maintain such inventories on a permanent basis. Financial support for corporate joint ventures in the area of inventory investments can have an effect in this direction. Joint ventures between companies that plan to build up and permanently maintain inter-company stocks of rare metals could be strengthened by a passive state participation subsidy. The economies of scale to be expected in the creation of such warehouses could further strengthen the positive effect.

5.3 5.3 Build-up of a public base reserve

Decentralized stockpiling of rare metals should form the core of a European reserve strategy, but a supplementary central basic reserve may nevertheless make sense for two reasons: as a geopolitical signal to raw material exporting countries and as a form of basic hedging for extreme supply scenarios. To facilitate coordination (free-rider problem between member states) and with regard to transaction costs (see section 4.1), this reserve should be centrally located at the European level. To limit costs and avoid crowding out private stockpile investments, it should be deliberately limited to a form of basic reserve containing only a selection of raw materials classified as particularly critical, and these only to an extent necessary to cover European consumption in a very limited period of time. The decisions necessary for this should be based in a scientifically sound and regularly updated risk analysis. The measures proposed in the first category to improve risk monitoring would be particularly important against this background.

Recommendation 7: Establishment of a management body

The first step in establishing a central base reserve would be to create a management body at EU level. This would have to coordinate the central purchase of raw materials and organize and manage the corresponding stocks. It would also have to monitor the occurrence of crisis situations and prepare for the possible release of reserve stocks in such cases. These crisis situations should be defined as precisely as possible by law. Cooperation with third countries in the joint procurement of raw material reserves (buyer alliances) could also be part of its remit. Finally, it should also review the reserve strategy itself at regular intervals. In particular, this involves decisions which rare metals in which sizes and processing forms should be held in reserve in the event of changing risk assessments. A merger with the previously proposed monitoring institution would therefore be advantageous. The body would explicitly not have the task of speculating and actively influencing prices on the commodity markets, for the reasons described in section 4.2. The financial resources of the management body could be organized in the form of a public-private partnership, also to ensure an appropriate financial contribution from European industry to the basic hedging service provided to it.

Recommendation 8: Design of distribution mechanisms

A basic reserve can only be of practical use if a mechanism for distributing stocks to affected companies is provided for crisis situations. This should also be regulated as clearly as possible by law in order to avoid conflicts. An EU-wide direct distribution to industrial companies would require a very complex distribution key, while a release into free trade could mean high procurement prices for the companies depending on the situation. As an alternative distribution channel, therefore, it would initially make sense to distribute resources to institutions in the individual member states. Basic indicators of economic strength and industry structure could be considered as distribution keys between the member states. The decision on the final distribution can then be made on the basis of national circumstances.

5.4 5.4 Transition to a different supply system

To eliminate existing raw material risks, Europe has no alternative but to fundamentally reorganize its procurement structure. Sources of supply must be diversified, while at the same time paying attention to the reliability and regulatory proximity of new partners. The development of intra-EU supply chains can complement risk mitigation, with a focus on secondary production (raw material recycling) in view of environmental goals and the comparative advantages of the European economy. Given rigid market structures, all these processes will take a long time.

Recommendation 9: Expansion of strategic partnerships

Strategic partnerships with third countries in the raw materials sector represent a promising instrument for establishing stable new supply channels. The EU is currently seeking to significantly expand its still limited portfolio of partners. In the short term, priority should be given to working with countries that are not only rich in resources but also have a well-developed infrastructure and regulatory proximity to the EU, making them suitable for the rapid establishment of joint supply chains. Australia, Norway, Canada and the USA in particular are natural partners under these circumstances. Raw materials cooperation with countries in which the necessary structures are still in the development stage should be viewed more as long-term projects. Here, efforts should first be directed toward exploration and institutional cooperation before economic integration is pursued. When selecting partners, care should be taken to avoid creating new one-sided dependencies. In addition to alliances with countries

rich in raw materials, strategic buyer alliances with countries such as Japan are therefore also important, as they increase Europe's weight on the global raw materials markets.

Recommendation 10: Expansion of metal recycling capacities

Greater participation by European companies in the processing of rare metals should be the second central pillar of a long-term raw materials strategy. However, Europe's future position in the utilization chain should be based on the comparative advantages of the economic area. And in the case of the relevant technologies of the future, these are generally located at the end of the chain. This applies on the one hand to the processing of refined products in downstream industries, and on the other hand to the recovery of raw materials from end products. Here, Europe should make greater use of its technological competence in the field of recycling. This would not only benefit general resource efficiency. In the long term, the transition to a material cycle that is as closed as possible could also reduce dependence on global supply chains with their questionable mining conditions and high price volatilities.

6 Conclusion

The variety of new resource risks that the transition to non-fossil technologies entails for Europe makes more active risk management in business and politics urgently necessary. Measures to diversify procurement sources and to promote Europe's own secondary production through raw material recycling are indispensable. However, they will only take effect in the medium to long term. In order to reduce procurement risks earlier on, the targeted build-up of reserves of critical raw materials is a sensible addition. Our analysis shows that stockpiling can help reduce both supply-side and price-related risks. This is particularly true in cases where markets are characterized by high price volatility and/or the risk of supply disruptions is significant. Moreover, if there is a high degree of market concentration on both the supply and demand sides, storage can also be used as a strategic tool for long-term price dampening. For the rare metals currently classified as critical by the EU, these conditions largely apply. Unlike alternative measures such as subsidies for the domestic mining sector, no hostile counter-reactions are to be expected from the globally dominant exporters, as they are also likely to benefit.

At the same time, it must be borne in mind that stockpiling, like any other form of insurance, can never be free of charge. In addition to the operating expenses for building up and managing inventories, the opportunity costs (lost market return on alternative investments) of building up reserves as a form of capital commitment must also be taken into account in the cost-benefit analysis. The aim of using raw material reserves to cushion risks in the future always goes hand in hand with foregoing consumption in the present. In view of the very dynamic development of technology and the susceptibility of the raw material markets to political intervention, intelligent stock management also requires permanent market monitoring.

Against this background, the question of practical responsibility is of decisive importance. Stockpiling should primarily be the responsibility of those actors who, due to their knowledge of the market and their personal involvement, are best able and willing to implement changes in the risk situation. In principle, this speaks in favor of decentralized stockpiling at the level of the raw material-consuming industrial companies. However, since there is a tendency toward underprovision, private storage should be supported by government incentive instruments. This could include special depreciation on raw material reserves, government guarantees for storage credits or subsidies for purpose-related joint ventures. State reserves of raw materials would also be useful as a basic hedge for the extreme

scenario of massive supply restrictions. These should be limited to a selection of a few particularly critical raw materials and, if possible, managed centrally at the European level. Their task should be limited to passive hedging in the event of a crisis and should not include an active role as a market player.

In general, further improvement of the information situation is required for active risk management in the rare metals segment. The EU has made considerable progress in this area in recent years through its expanded criticality monitoring and the data collection of the Joint Research Centre. However, continuous risk monitoring would require the development/consideration of additional indicators (especially on the market situation and the use side) and a more differentiated evaluation system. In addition, more attention should be paid to the dimension of environmental-social risks in the raw material analysis.

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