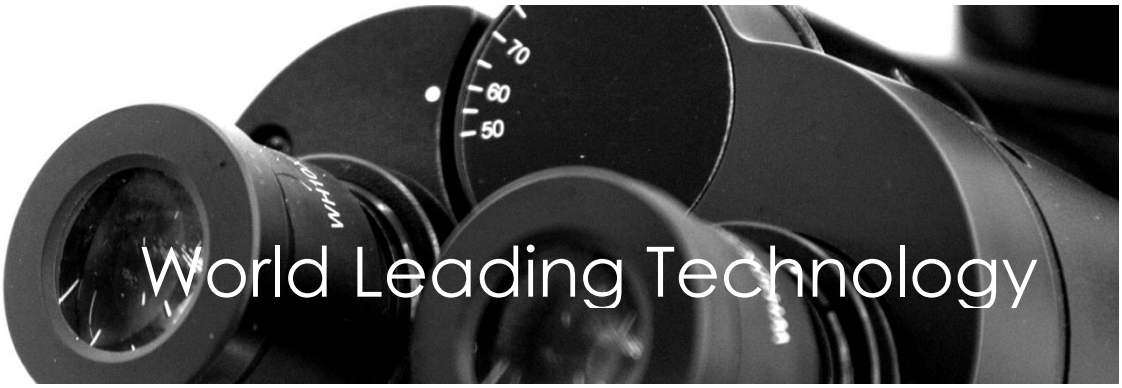
MINBAS INNOVATION

AGENDA

A Research and Innovation Agenda for Minerals, Aggregates and Stone



<< …By innovation, we mean that knowledge has been transformed into new values. It is about developing products, services and organization in both the private and public sectors. … >>

(IVA. 2011 - INNOVATIONSPLAN SVERIGE)

MINBAS Innovation Research Agenda

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SUMMARY

The strategic agenda, "MinBaS Innovation", describes a vital area of investment for the country's growth as well as sustainable societal development. The field of the agenda deals with very large volumes of material, and improvements in the production and distribution chain are resulting in noticeable effects. Together with research organizations, industry can have an effect on some parts of this, but this requires an extensive collaboration with the rest of society in order to gain momentum and to increase the speed of this development.

The agenda focuses on:

- Measures to create a long term sustainable supply of construction materials for society and of mineral based products for important industrial processes
- Material supply with best available techniques, energy efficiency, environmental consideration and safety
- R&D, technical development and competence for the future
- Domestic and international co-operation

The agenda suggests actions to be taken in order to achieve the goals.

What is **MinBaS**?

The name MinBaS comes from Mineral, Aggregates and Stone.

Through their trade associations, the industrial mineral, aggregate and dimension stone industries own a company, MinBaS AB, for the purpose of conducting research and development.

The name of the agenda, MinBaS Innovation, reflects the intention to conclude research already underway as well as perform new research, and to disseminate and implement the results (innovation).

CONTENTS

INTRODUCTION

The strategic agenda, "MinBaS Innovation", describes a vital area of investment for the country's growth as well as sustainable societal development. The agenda focuses on the need for measures to be taken within research, technical development and innovation in order to generate a long-term sustainable supply of ballast, natural stone and industrial mineral-based construction material for the building of infrastructure and of mineral-based input goods for vital industrial processes.

Society's need for industrial mineral, aggregates and natural stone

Nationwide, the demand for construction material will be high for quite some time to come. According to a decision made by Parliament, during the period between 2014 and 2025 Sweden shall invest a total of 522 billion Swedish crowns on transportation infrastructure, i.e., roads and railways. According to the Swedish National Board of Housing, Planning and Building, in its survey from 2011, a new addition of more than 40,000 to 50,000 new apartments per year within the next few years, and at least 35,000 new apartments per year for the foreseeable future will be needed; in addition, there will be increased investments in renovations for the large supply of residences from the 1970s.

There are also substantial industrial investments under way in the country, for example, the expansion in Malmfälten, where factory and industrial construction constitute a considerable portion. The demand for lime products for important export industries such as the pulp-and-paper and steel industries, as well as other applications follow the pace of the economic trends in these sectors.
Urban development also requires quantities of products for the design of a well built-up environment, for example, natural stone deposits, concrete platforms, walls, conduits and the decoration of common areas.

Supply

With its 90 million tons per year, ballast is the country's most important raw material in terms of weight, next to water. Ballast is used for building and construction purposes. The greatest area of application is in the construction of roads, where the material is found both in the substance of the road and the surface layer. The material is also used in railway embankments, ground-levelling and as an ingredient in concrete and asphalt, in which it constitutes approximately 80 and 90 percent of the content, respectively. Ballast is produced all over the country, but the largest production takes place in highly populated regions.

Crushed lime, an ingredient in quicklime and cement, is ton for ton, the most significant industrial mineral. Yearly production was approximately 7 million tons in 2010 of which approximately 4 million tons went to the production of cement. Gotland is the most important region for the production of limestone.

Cement is principally used in concrete, which is one of the most important construction materials for the construction and building industry (the building of houses, bridges, tunnels, roads and railways, dams, water and drainage systems). Ground and quickened lime products have a very broad range of uses in our society.

<< Each person in Sweden uses about 12 tons of these products every year. This corresponds to a large truck loads per person per year! >>

Quickened lime products find their largest markets within the iron and steel industry, and in the pulp and paper industry where they make up a vital filler material in the production process. They also have a place in the building and construction industry, in the filtering of flue gases, water purification and the chemical sector. Ground lime and dolomite products also have an equally large field of use, but in addition they are also used in agriculture and in the liming of lakes.

Sweden has a bedrock that is old and in some respects unique. Swedish natural stone is highly prestigious among the world's natural stone consumers due to its very good technical qualities and appearance. The most common areas of use for natural stone are paving (streets, squares, roundabouts and garage ramps), walls, building facades, roofs, stairwells, floors, countertops, gravestones and works of art. 85% of the block stone production is exported to markets worldwide.

At present, there is no sustainable alternative to the indigenous construction materials and

industrial minerals in their fields of use. It would be macro-economically devastating and would even entail an increased strain on the environment to import this enormous volume of material, as importation involves long-distance transportation and often production from countries with inferior environmental standards. The society would also suffer from a loss of jobs in Sweden and it would become an issue of security from a supply perspective for urban development and for the country's export industries such as steel and paper.

Within the EU in recent years, the supply of raw materials has been highlighted as an important future issue. Political worries concerning unreliable deliveries, increased prices for raw materials and even reduced assets have resulted in a focus on this matter resulting in the EU now making great efforts in as much as possible making the EU self-sufficient in raw materials.

The EU's new raw material initiative lists ballast, natural stone and industrial materials as the materials which, together with metals, constitute the foundation of the EU's future raw material strategy focusing on the provision of non-energy-related raw materials. A number of initiatives are planned within the European Union in order to support research, development and innovation within those industries that work with the production of raw materials. All member states have been asked to develop their own national mineral strategies.

The Swedish Mineral Strategy

In February 2013, a new Swedish mineral strategy was presented, which was prepared by the Ministry of Enterprise, Energy and Communications with the support of inter alia the Swedish Geological Survey, SGU.

The Mineral Strategy is the cornerstone of the work with MinBaS Innovation and the agenda is in line with the strategy. Among the proposed measures in the mineral strategy, the following are worth mentioning:

- Analysis of the recycling and extraction potential
- Methods for regional material supply planning
- Establishment of a mineral forum
- Increase awareness of the role of geology in society
- Forms of integration between researchers involved

In working with these points, industry can participate within the framework of the MinBaS innovation agenda.

Challenges and the need for action

The most important challenges and the needs for achieving sustainable development within the agenda are:

- Securing raw material assets and optimal localization

- The supply of expertise and integration between industry and academia
- International cooperation
- Efficient and sustainable production processes
- Sustainable products and application systems

The Supply of Raw Materials and an Optimized Licensing Process

For a sustainable supply to society: Ballast, industrial material and natural stone are not classified as extracted minerals according to Swedish Minerals Act; rather, permits to conduct such extractions are issued by the county councils, and such activities are scrutinized according to the Environmental Code. The companies need to enter into contracts with the particular landowners in order to engage in production. Access to raw materials and permits for extraction form the basis for all supply. Prospecting and survey work show where ballasts of suitable quality are available. The licensing processes for beginning a new operation can then be both time and cost intensive. This is where such things as society's need for the products are weighed against environmental concerns and against conflicting desires, for example, that the land to be used for building or recreation. In the future, it will be necessary to have a collaboration between industry, official agencies, and regional and local interests in order to create an objective method as a basis for localization, a better consensus regarding the economy of such commodities and a uniform legal framework that serves to channel the resources in the right direction.

For competitiveness: The industry needs to improve its information about its operation's benefit to society in order to facilitate the establishment of new finds and to generate acceptance in the community. Raw material assets in Sweden are unique and a well-planned extraction with the utmost regard for the environment results in a competitiveness in which increased exports can be possible.

The Supply of Expertise-Integration between Industry and Academia

Knowledge banks in interaction and functioning networks: There is a need to reinforce the technical development by means of an increased dynamic interaction between major and minor companies, universities, colleges and institutions. Within MinBaS industries, there are many small companies and most of them have limited experience of what the academic world can offer them. At the same time, universities and colleges have too little contact with industry and its companies. Improving skills and making progress requires an interaction and an exchange of knowledge between the companies and academia. Coordination and collaboration between the companies, professional training and academia are of the utmost importance.

Relevant training at all levels from operator to researcher: Interest in geology and rock engineering is currently low. Within the Swedish mineral strategy, SCU has been given the task of increasing awareness of the role of geology in society, which clearly is needed. Many were employed during the "record year" of the 1960s and will soon retire. Interest in working in practical professions is low, in spite of a high degree of unemployment among young people. A future more highly technological and resource-efficient production technology will place higher demands on technical training. At present, there are a number of established training partnerships between academia and MinBaS industries and these need to be strengthened. One example of this is Berskolan's training of engineering technicians and other schools for vocational training and the unique professional stoneworker's training at Stenforsaskolan.

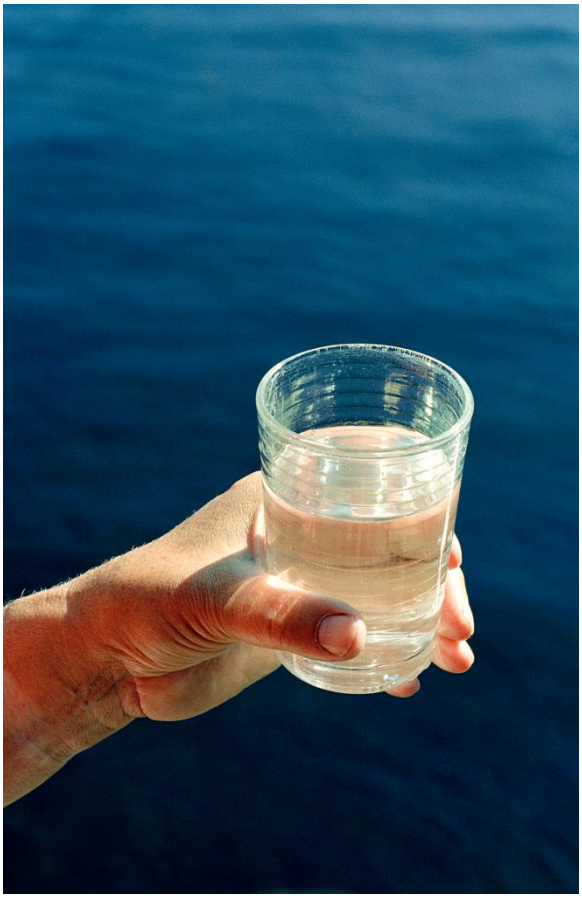
There is also a need for teacher resources with specialized knowledge about industrial operations and the connection to societal development. Geology as a subject must also receive a more apparent place in the education. Teaching materials must be renewed both respect to the ongoing development and with respect to teaching methods that will be applied in the future.

International cooperation

In order for Swedish industry to maintain its competitive edge, a constant monitoring of the world around is necessary in order to follow up on production efficiency and the need for product development. This is done every day at the level of the individual company and many companies are parts of internationally active conglomerates that continuously exchange experiences.

At the industry level, the companies are also, via their Swedish organizations, part of European industry organizations that monitor what is happening in the EU with regard to regulations, production and marketing conditions and support for research and development within each sector. Most research organizations in the MinBaS network are currently involved in the EU's various research programs or in international programs, in many cases in cooperation with Swedish companies.

Industry associations also take part in the various EU-based arenas that exist for the integration and planning of focus areas within research. In order to develop the research base further upon an implementation of major research programs directed toward global societal challenges, it is important to have an exchange of experiences and cooperation in optimizing resources, especially when it comes to such things as the building of expensive test facilities. In the vision's concept of "world-class", there is an active monitoring of the world around which entails the supply not only being "sustainable", but in being so all while using the lowest possible input of working capital and in using renewable energy sources, which is a challenge.



Swedish industry needs to have a large involvement in the European research programs and needs actively to spread knowledge internationally about the research efforts made in Sweden. This makes it easier at the next stage to benefit from the experiences of others. Those who give can more easily get. In order to increase involvement in industry and in the research organizations for international cooperation within joint research programs, the work should be developed further in the European arena, on which one is already participating. That is where one should strive to see that efforts are made within the areas of need that Swedish industry prioritizes.

Industry and research organizations should allocate resources to increase the exchange of information and cooperation primarily at the European level by taking part in important arenas, conferences and through their own proposals and articles. A cohesive Swedish platform also needs to be created by several research organizations in order to obtain a base and the gravity in the work, which is needed to take part in the most often in March EU projects that are highlighted.

Effective, sustainable production processes - good use of resources

All mineral extraction is currently considered a process industry, and the requirements placed on the companies from customers and the world around are in principle the same as those placed on all other process industries. However, there is an essential difference. In the mineral industry, production is based only on specific commodity, i.e., material from the find being extracted. This raw material varies in composition between various finds and even within each particular find. It is very difficult to foresee the variations in advance. It is only once you get into the production phase that the qualities can finally be determined. One major challenge is thus to create better awareness in advance of a commodity one intends to extract.

In order to be able to develop a viable rock mineral industry in the long term, we one must concentrate on achieving an optimized and integrated production process which yields products of a consistent and high-quality. Geological information and classification methods are needed in order to be able to find and exploit new discoveries. In order to develop new breeding and processing methods and to inspect the quality of the products in existing operations, there are basic skills are needed

concerning the properties of the ballast. Planning, managing and control systems must be based on new physical measuring methods and interpretive models. In order to optimize the entire production chain, models and techniques need to be developed in order to facilitate automation.

New requirements for a better environment and work environment mean that efforts toward the development of new production systems, methods and equipment that reduce environmental impacts become more significant and must be included in all development of the production process. The demands on the exterior environment and work environment also increase in the new regulations (dust, noise and vibrations and restless management) and stay one step ahead is another challenge for the industries. The safety aspects in the production must be emphasized in order to create a better working environment through the implementation of new systems.

Safety and work environment efforts are high priorities within the industry. Clean air will be the focus for the EU environmental policy discussions in 2013, "Year of air". The European environmental agency (EEA) provides a large quantity of information forming the basis for monitoring the air pollution legislation. In the review of the EU air policy for 2013 (EU Thematic Strategy on Air Pollution and related policies, TSAP), we find inter alia a review of mobile off-road machinery.

Energy and environmental policy goals: Reduced energy usage and reduced CO_2 emissions

The national energy policy goal states that by the year 2020, 50 percent renewable energy shall be used, of which 10 percent shall be renewable energy within the transportation sector, the energy use shall be 20 percent more efficient [a sector-wide goal] for reduced energy intensity of 20 percent between 2008 and 2020) and the emission of climate gases for the non-trading sector shall be reduced by 40 %, of which 2/3 is within Sweden. The European system for trade in emission rights will in the face of the upcoming period of 2013-2020 gradually reduce the allocation of free emissions right to industry. At the same time, the prices for energy on the world market have grown steadily in recent years. The International Energy Agency has in its technology road maps for different industries, such as the cement industry, determined that it is not enough to have general energy savings in production and in replacing fossil fuels with more CO_2-neutral fuels in order to achieve the emissions reductions needed globally to meet the thread of climate change.

This means that techniques and systems for the separation and storage of carbon dioxide, so-

called Carbon Capture and Storage – CCS, must be introduced in the energy sector and in industries such as the cement and lime industries. The current so-called BAT techniques for CCS are very energy intensive and there are considerable uncertainties with regard to the means of storing CO_s in the vicinity of Sweden and with regard to the regulations; the Swedish directive only stipulated storage in aquifers under the surface of the sea. For the cement and lime industry which has a very energy intensive production processes and which is also under a lot of pressure to reduce CO_2 emissions, energy savings, development of effective CCS methods and regulations are of vital importance.

For heavy industry fields such as the quarrying, industrial minerals and natural stone industries which process large volumes of heavy materials in the extraction and have a considerable share of vehicle transports in their production, the constantly increasing energy prices pose a challenge. Each saving and simplification thereby yield considerable effects in the form of lower resource requirements, better environmental benefits and increased competitiveness. There is a need to investigate and develop planning systems and comprehensive logistics solutions.

All in all, new equipment and new production systems need to be introduced in the breaking and process steps with the aim of minimizing energy consumption and improved commodity yields and product qualities.

Other national environment goals – phasing out of natural gravel

Within the framework of the Swedish national environmental goal for ground water of quality,

Example of restored quarry

there is an aim to phase out the major proportion of the use of natural gravel by the year 2020. For ballast – and the concrete industry which currently consumes 44 % of the natural gravel in concrete, the phase-out of natural gravel has posed an extra challenge. A technological breakthrough has occurred within the ballast industry as the larger portion of the production of ballast in the future shall be done with crushed ballast, and that is where the replacement of the fine fraction using wholly crushed material is the greatest challenge.

This means that new production methods and systems must be developed, the means of identifying the right quarried commodity must be improved and a comprehensive product development is required within the various fields of application.

Sustainable products and application systems – life-cycle analysis, recycling

Product development, both of residual products and of natural commodities are strongly connected to the production processes and market trends. The building and construction industry, the processing industry and society require large volumes of construction materials and input goods of consistent and high quality and at low prices, produced with the least possible environmental impact. The products within the MinBaS sectors are most often assessed according to the functions in the intended field of application; they are not sold at established marketplaces as are, for example, metals, rather there is a contract between the producer and the end user. At the same time, the customers are traditionally conservative and putting out new products that better serve the customer's needs is a clear challenge.

Product development and customizing products must be given special importance within the industry that produces ballasts, natural stone and industrial minerals. It is most often the function of the product in the field of use or a visual quality that is crucial to marketing opportunities. Development must therefore take place in close cooperation with customers, builders, authorities, researchers, consultants and equipment suppliers. The solutions that come forth may need support in the form of demonstrations that can actively contribute to showing the market that the product or application actually works in reality.

New measuring and control methods must also be introduced which can yield better control and inspection in the production and a consistence product quality.

When developing products for civil engineering today, there are considerable requirements placed on the certification of the products, which is why standardization efforts with development and implementation of relevant measuring methods are of great important in the development work for the acceptance of the product on the market. Life-cycle analyses for declaring the production and products from a sustainability perspective is an important part in the acceptance of the product on the market.

Recycling – Residual products and mineral-containing industrial products

Within MinBaS industries, the quantity of residual products is small compared to the volumes in the mining industry, and the products are most often considered inert. The material most often finds an outlet, but how it takes before this happens can depend on the state of the national economy. However, it is important to continue to strive toward all products from production, even those that are not easy to move on the market, finding new areas of circulation. In order to achieve a long-term environmental production, new fields of use are required for the residual products that are generated through the production, and there is a desire in the community to increase the recirculation of mineral-containing industrial products.

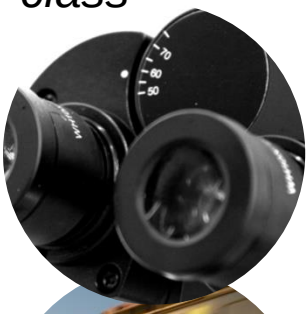
The work dealing with systematic recycling has begun, but there is still a need for major investments in order to develop simpler, more efficient and safer recycling systems.

This pertains both to the processes themselves and to the products, but it is also about increasing awareness among the customers and a functioning regulation. Recycling also has a good effect on energy usage. Within the ballasts industry, one estimates that approximately 30 % less energy is consumed when recycling as opposed to a new extraction. The EU aims to have at least 70 percent of all building and demolition debris shall be recycled by 2020. Sweden has quite some way to go before reaching that goal. Both recycling technology and verification and demonstrations will be needed in order to generate market acceptance.

VISION

The vision is based on the insight of the significance of the construction material and the industrial mineral to future civil engineering and as input goods for the Swedish processing industry. Only by using the processes and systems that generate the least possible external and internal environmental impact can one maintain competitiveness and gain the acceptance of the market and secure the future supply of manpower to the industry.

Sustainable supply of rock materials in world class



World Leading Technology

Leading position and active monitoring of technology and expertise

Sustainable Society

Climate neutral production in which the value chain "production to use" is optimally resource efficient

Excellent Safety

A strong safety culture with machines that are designed for minimal risk of injury

World-leading technology

One does not need to manufacture every little part oneself, but one must know how the processes work and what is possible. It is about knowledge and orientation – on a large and small scale – and it is about what is relevant and important to our industry, our research and our society. Through Swedish research and industry, we already have world class expertise in most important fields.

Here we have contacts with people and organizations in other locations and parts of the world, which allows us to monitor what is happening. It is important to continue with these contract and one aspect of MinBaS Innovation's vision is to expand the network and to make sure that younger employees have an opportunity to take part in skills development. That which was considered relevant knowledge 5 years ago may have changed, and it is important to sense these changes and to have the opportunity to take a position on what they mean for our Swedish industry and research.

Sustainable society

Extraction and processing of products is done without unnecessary losses and with such method that the production's overall footprint becomes zero. The vision is based on new and improved production methods, the machinery and other equipment of the future, good planning, the use of energy sources without affecting the climate, minimizing waste, recycling of material and safety in the job.

The entire value chain from extraction to use and recycling are optimally resource efficient. This means that customized products reach the customers after having been produced without wasting resources. The material has properties given them a long life and a low life-cycle cost.

One must have a holistic view that takes production, usage, recycling and disposal all into account.

Excellent safety

The risk of accident decreased through the production of new safety devices and safer machinery designs. Efforts for clear air in and around facility will come about exactly as EU's environmental policy discussions for 2013 will be in focus, as well as measures to reduce vibrations and noise.

The risks associated with internal transports in the pits shall be identified and minimized.

The culture of safety among the employees in the industry is improved through increased awareness and improved routines. Joint training with regard to work environment and safety is prepared.

The improved worked environment and safety culture lead together leads to a realistic vision of having zero accidents.

GOAL

The goals within the agenda are divided into short-term, medium-term and long-term goals.

Short-term goals (2016)

The short-term goals is for MinBaS Innovation to have started off and mainly to have concluded the projects that started in 2013-2013 and which are scheduled to be complete in 2016. The goals of the projects are set out in the project descriptions for each particular task.

Medium-term goals (2020-2030)

In the medium-term, measurements (indicators) are created that can be used in order to show the effects of the task. This way, one can begin measuring and verifying the changes.

These measurement primarily include:

- Securing raw material assets and optimal localization
- The supply of expertise and an integration between industry and academia
- International cooperation
- Efficient and sustainable production processes
- Sustainable products and application systems

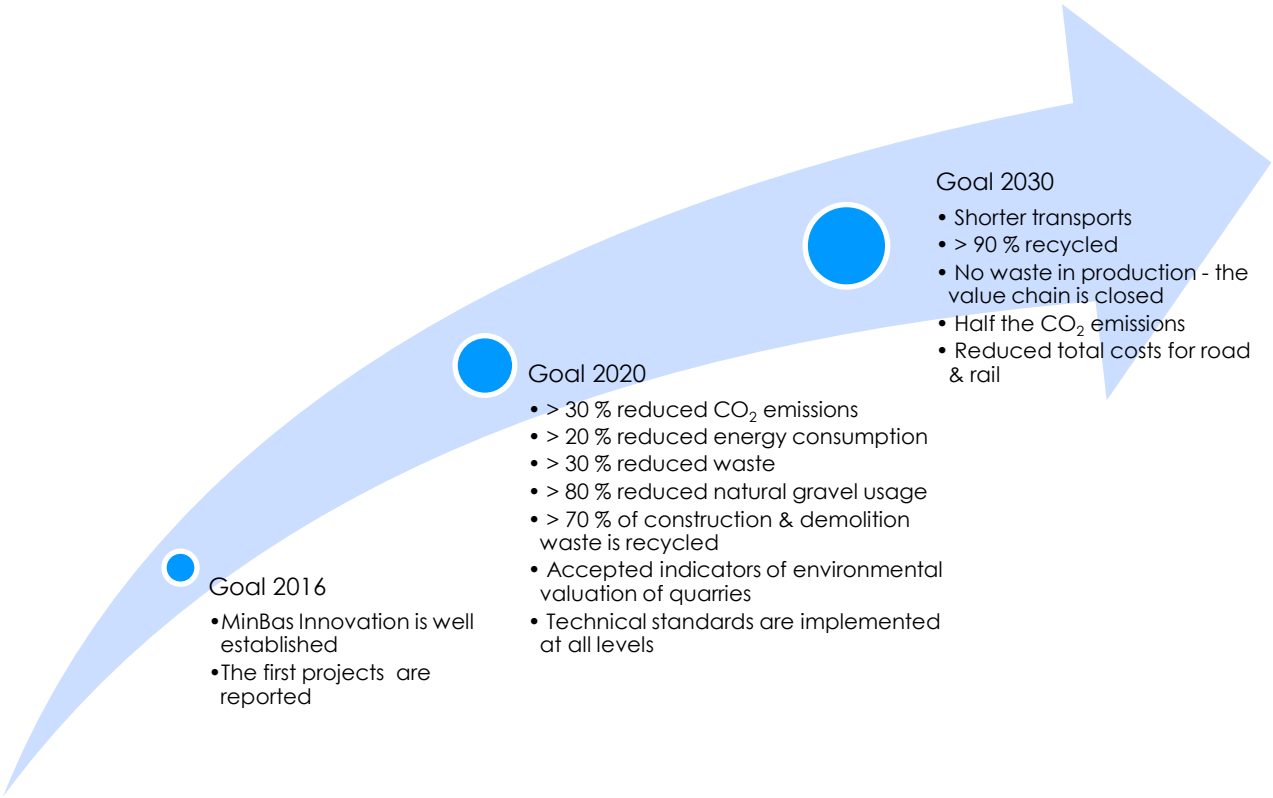
Common goals beyond 2030

Based on the challenged described in the first chapter, the long-term goals for MinBaS Innovation will be to take on these challenges and to achieve change and noticeable improvement within each area. It can be difficult to measure this and to set targets for the overall challenges.

Optimal localization involves lower transport costs, traffic risks and environmental emissions and reduced road wear. Optimal localization of pits would inter alia be based upon clearer criteria for how the suitability of a location is for a pit shall be assessed in comparison with alternative locations and the possibility of better highlighting how pits can be used in a new way, both parallel with the pit operation and once the pit operation has concluded.

Supply of skills: To be able to create attractive workplaces for young people, whose demands are different than those of previous generations, one key issue is how to attract new, young, highly productive employees. At the same time, more and more elderly people need to keep working past the age of 65. Both of these needs mean that workplaces of the future with a focus on man-machine, automation and ergonomics must look considerably different than what current workplaces do, especially in the mineral industry.

International interaction and efficient production processes: The production of the future is characterized by complex systems, a high level of technology and an ability to change in the organizations. The mineral industries have been relatively low-tech and therefore like have a great potential for efficiency measures. New technologies and systems can only work optimally if the interaction between man and production system is improved. Our vision of "world class" means that we shall nurture networks and make sure that younger employees get the opportunity to take part in skills development. The ability to change, the capacity for constant development of the enterprise and innovation management skills will always be vital skills.


Goal 2016
•MinBas Innovation is well established
•The first projects are reported
Goal 2020
• > 30 % reduced CO_2 emissions
• > 20 % reduced energy consumption
• > 30 % reduced waste
• > 80 % reduced natural gravel usage
• > 70 % of construction & demolition waste is recycled
• Accepted indicators of environmental valuation of quarries
• Technical standards are implemented at all levels
Goal 2030
• Shorter transports
• > 90 % recycled
• No waste in production - the value chain is closed
• Half the CO_2 emissions
• Reduced total costs for road & rail

FOCUS

Areas of research

Three strategic areas of research have emerged as being the most highly prioritized:

The Production Process, Products /Applications and Stone in Society

A number of contributions have been identified for these areas which correspond to the research needs and the challenges. During the agenda work, an open announcement was made among those involved in the agenda, companies and research groups in which everyone was asked to submit suggestions for research efforts within the three strategic research areas.

The efforts are in certain cases specific to each sector, others are common to all three. Some research areas have been conducted from MinBaS I via MinBaS II or within the Energy Programmed 2007-2010.

In some cases, the results from the research and development work are now conducted within MinBaS Innovation in the form of e.g., demo projects and/or are marketed / applied together with customers. These will thus be of a typical innovation character. Other areas have shown to require continued research and development work. New challenges have come up that motivate research and technological development efforts.

Through MinBaS Innovation, the possibilities are greatly improved for the knowledge that has gradually been acquired in earlier research programs such as MinBaS I and II and the Energy Programmed to approach a broad implementation in the industry by users and society.

Expected results and effects

As shown in the image below, the results in the focus areas that have been prioritized within the agenda contribute to a great degree to the agenda's visions and goals being realized. This is in the short, medium and long term.

The production process

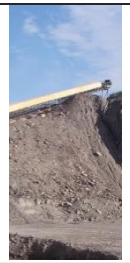
The production process of finely crushed rock, industrial materials and natural stone are streamlined and optimally resource efficient. This is achieved by developing technology, new research methods and planning systems. Sustainable burning processes for cement and burnt lime are developed. Workers' health and safety is improved and the risk of accidents is reduced by safer machines and improved safety culture.

Products & Applications

Sustainable products for civil infrastructure are developed based on rocks, minerals, and natural stone. For aggregates, this includes the development of substitutes for all application areas of natural gravel. Within the natural stone industry new products and application systems are developed. For cement and lime industry, the focus is on developing products with less environmental impact.

Rock materials in society

More indicators to assess the environmental impact of the industries are developed, in order to facilitate the advance of common goals and guidelines. The transfer of knowledge to future generations is ensured by competence development. Collaboration between industry and universities is increasing and international collaborations are strengthened.

		Actions	Outcome targets	2016	2020	2030
Production process		Preliminary investigation methods and planning systems	Energy consumption	-10 %	-20 %	-20 %
		Production of finely crushed aggregates and industrial minerals	CO_2 -emissions	-10 %	-30 %	-50 %
		Energy efficient combustion processes for cement and burnt lime	Proportion of new processes implemented	10 %	30 %	50 %
		More efficient processes for the production of natural stone	Absence from work	-5 %	-10 %	-15 %
		Occupational safety and health in production	Proportion of serious accidents	-40 %	-90 %	-100 %
Products & Applications		Product development for civil Infrastructure	Share of new products on the market	10 %	30 %	50 %
		New products and application systems in the natural stone industry	Share of recycled aggregates	10 %	30 %	90 %
		Environmental products in the cement and lime industry	Increased volume of natural stone use	10 %	20 %	30 %
		Replacement for natural gravel	Reduced natural gravel extraction	-50 %	-80 %	-90 %
Rock materials in society		Raw materials and the environment	Assessment systems used	20 %	40 %	60 %
		Indicators for the industry's significance	Number of indicators used	20 %	50 %	100 %
		Competence development training	Number of projects and thesis work	10 new	20 new	30 new
		Coordinated activities industry / academia	Number of graduate students from industries	4 new	6 new	8 new
		International networking	EU project with participation from MinBaS	2 new	4 new	6 new

Vision

World Leading Technology

Sustainable Society

Excellent Safety

Renewal

The suggested focus areas for research and innovation within MinBaS Innovation's agenda contain projects within the entire value chain of the production process:

From the characterization of the raw material, via breaking and processing, to development of the finished product and application as well as the procurement of mineral-containing products for recirculation and processing of residual materials from production into saleable products in new areas of use.

Within each focus area, this program will be located high up on the value chain than previous programs, which entails a renewal. Many projects are far ahead in the development and some are already ready to be demonstrated on a large scale in collaboration with the industry.

The technical development projects are also support with the ongoing theoretical skill-forming projects, which increases the values of these projects by means of the "processes" being gradually improved. The possibilities of quickly being able to reap the benefits of the new processes and products are great for both raw materials' producers and customers as many projects are far ahead and are ready to be demonstrated. For participating suppliers of equipment and services, this means that one is closer to a commercialization of the developed technology & systems.

Comprehensive view and connection with value chains

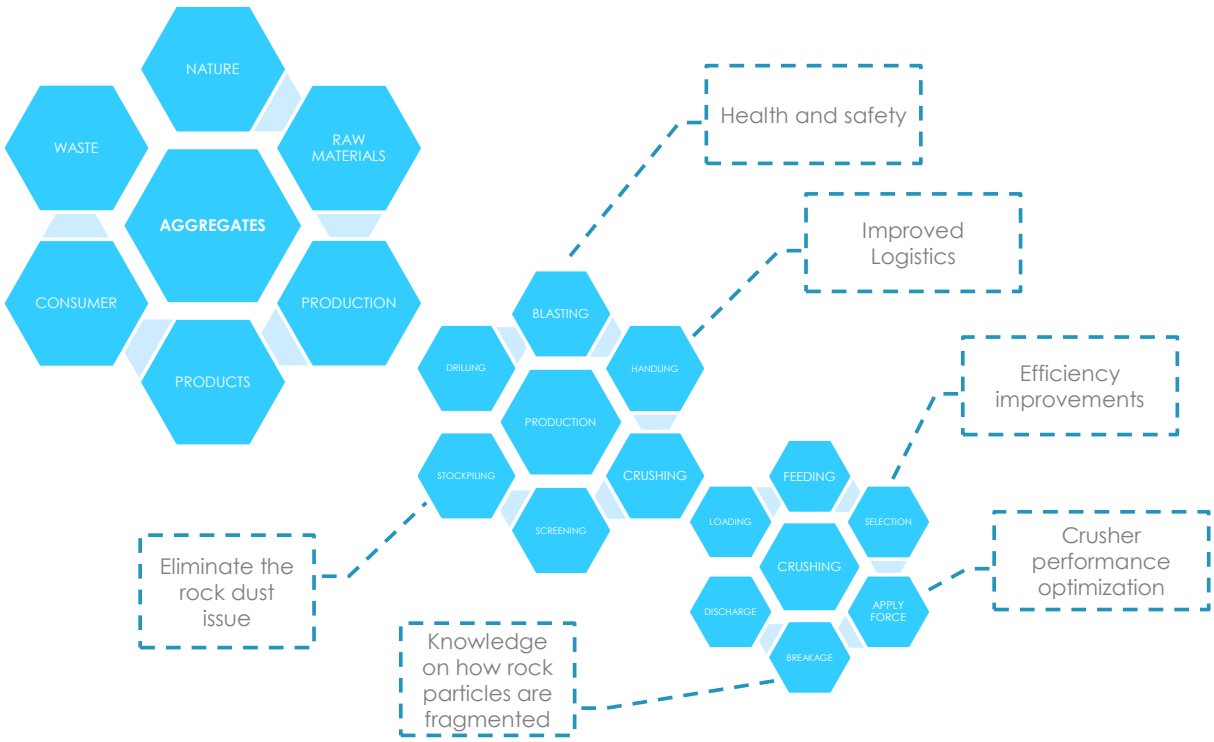
By looking at the entire value chain, new opportunities can be discovered that are not clear if one only focuses on a small part of the value chain (total optimization instead of sub-optimization).

For ballast, one can develop the various parts based on a principle image of the key factors. With a life-cycle based production and an insight into the fact that the market needs functional products, one realizes that the possibilities for recycling should be considered to a greater degree than they are today.

By developing and implementing production systems and processes that recycle resources, possibly in combination with virgin material, what today is a disposal problem for demolition companies, can become a resource for society. The costs of disposal tell us that recycled products can compete.

Examples of obstacles to achieve a closed value chain are standards, regulations and directives, but even a circle of customers bound by tradition. Technical development in processing and verifying of properties (for CE

Example of coupled value chains for aggregates and crushing. By identifying value chains, research and development efforts are linked to the aims and effects



labelling) are necessary elements to overcoming these obstacles.

New mineral processing methods, for example improved crushing methods, dry and wet grading, as well as grinding and separation methods can be developed. More energy-efficient production processes such as the optimizing of the entire production chain should be investigated. Further applications of IT support, especially machine and process control should be developed so that the production becomes more industrial, such as more exact blasting techniques with less explosive residue.

System faults and challenges in value chains

Traditionally, each part of the value chain sees to its needs and possibilities – for example, the technical value chain can be from drilling-blasting, to ready and approved road be considered like the example of the crushing process in the image above. In addition, the work before the pit is made with site surveys, land owner contracts, applications for pit permits, appeals to higher authorities etc. can be added.

Through communicative gaps between different parties in the value chain, potential rationalization affecting several stages in the value chain have traditionally not been identified or they have been neglected as they are presumed to be outside the area in which one had one's own decision-making power. The MinBaS agenda shall serve to consider the entire chain from a socially beneficial function.

The various process steps within industry are developed and rendered efficient individually to much too great a degree. A better interaction between the parts of the value chain can generate considerable benefits in efficiency. Some examples worth mentioning are the blasting of rock, which can then be refined. An optimal blasting with a good fragmentation means that loading, crushing, grinding etc. can be done with a considerable smaller input of energy, time and other cost-intensive resources. All in all, it can be worth focusing more on the blasting step.

Life-cycle analyses, LCA, of the value chain from prospecting to use and eventual recycling of the material are lacking. An LCA analysis would be a good basis for assessing the environmental impact of a particular measure.

At present, the industry is not regarded as an especially attractive workplace, which makes the recruitment of capable youths to the industry difficult. The number of places at relevant university courses is too small. Some people regard the industry as dirty and dangerous. It must become safer in order to attract more people. This is where interaction within the EU and with similar branches can yield results.

Production equipment such as crushers, sieves and transport vehicles constitute heavy and long-term investments. The equipment used today is at times not constructed with especially high ambitions with regard to noise and other environmental effects. With better technology, the possibilities of using the investments during a greater part of the day would increase.

Environmental, cultural and natural values are difficult to value in terms of money, but still they can be summed up in a comparable manner. Today there is a lack of tools for quantifying and evaluating disturbances to the natural environment and evaluating the man-made environment in various conceivable localizations, which is needed when applying for licenses for undertakings. A more objective tool for such considerations is lacking for both the applicant and the examining authority.

The implementation of knowledge requires demonstrations where financing is greatly uncertain. Test facilities and demonstration facilities are very capital-intensive.

The implementation in industry and in society of new technology and production and application systems and thereby the goals and effects for the medium and long range are governed by the national economy and a general downturn can substantially impact the opportunities for implementation, as can dramatic changes in prince and access to e.g., energy or fuel.

In the area of skill-driven development, a much stronger interaction between the companies and academia are required; here there is a certain degree of uncertainty with respect to fulfilling goals in the medium and long term as it is affected both during economic upturns and downswings. This applies mainly to small companies, where an economic upswing means that they often have too much to do and cannot allocate staff to take part in the collaborative projects and training activities.

POTENTIAL FOR THE INNOVATION AREA

Position of innovation area

Those parties and organizations that are behind the agenda have extensive experience in both cooperation in research as well as in innovation. This yields a high potential for realizing the goals set out and the visions which the agenda describes.

Industry structure within ballasts, industrial minerals and natural stone

The MinBaS industries market products based on the extraction and recycling of ballast, industrial minerals and natural stone as previously described. Annual Swedish production of these materials total roughly 100 million tons with a value of approximately SEK 10.5 billion and employs just more than 9,000 people.

MinBaS industries consist of a very large number of production units and companies of various size. Within the ballast industry, there are smaller companies, but especially within the natural stone industry that number of small family businesses is significant. In 2009 (the last year that official statistics were published with regard to ballast), Sweden had a total of 1,589 production locations for ballast in the form of natural gravel and crushed ballast. Almost half (705(of the producing pits supplied between 1 and up to 10,000 tons of ballast. At the same time, there were 884 pits that supplied over 10,000 tons of gravel material. In the county of Norrland, there is a relatively large number of small pits, most often natural gravel or moraine pits which in many cases only supply up to 500 tons. In counties with large cities on the other find, one will find many large pits and then often in the form of rock quarries, which are part of large conglomerates. In groups with more than 110,000 tons in annual production, most pits are within e.g., Stockholm county, Scania county and Västra Götaland county.

From SGU's pit statistics from 2011, it can be seen that 41 pits supplied industrial minerals, of which three companies dominate within the production of lime; there is only one company in the country producing cement. 58 pits supplied natural stone and there are a few large corporate groups in this industry. The production of industrial minerals and natural stone is located primarily in the southern portion of the country. The industrial mineral industry and natural stone industry is active on a market that is exposed to both local and international competition. Industrial minerals have an export market and a large share of the block production within natural stone is exported (85%). The ballast has thus far not faced major competition from imports, while the domestic market is exposed to competitive forces.

This industrial structure with a large number of production locations and a mix of small and large companies makes special demands when the research cooperation is to be conducted within joint programs and projects. This has been one of the strengths of the MinBaS program in that one succeeded in satisfying the needs of all types of companies and that the development has been conducted within all subsectors. This is also one of the factors that should be considered within this agenda.

Equipment suppliers and service companies

In Sweden, there are a number of internationally technologically leading manufacturers of equipment and goods for ballast and mineral production, such as Atlas Copco, Sandvik, Metso, Orica, Kimit, ABB etc., which continually conduct research and development cooperation with producers of ballast and industrial minerals. Right now a number if such projects are underway and it is important that the collaboration be able to be further developed in order to drive the implementation of new processes and systems in the industry. Furthermore, this can create opportunity for participating equipment suppliers and service companies to develop machines and systems, as well as services for a global market.

There are also several leading smaller companies which market machinery and other products for the quarrying sector, e.g., Norab, Maskinmekano Mogensen and Tesab. Among Swedish consultant companies, there are a number of large and many small ones that have special expertise in rock excavation technology and the use of ballasts and minerals.

Higher productivity and less disturbance for those living in the vicinity are two goals: The less noise and dust that come out of the pits, the easier it is to get to establish new pits and to operate pits in the evenings and at night, which allows productive capital to be used more effectively.

Research structure in Sweden

Sweden is a small country, but at times this can be an advantage. The contact routes are short and informal. By means of the long-term

cooperation between the quarrying and mineral industry and universities, colleges and institutions, a good familiarity with the company's challenges and the needs for development have been generated in academia. Currently, there are a number of research groups within academia in particular locations in the country that have expertise within various parts of the production chain – from geological characterization and production methods to product development. Sweden is also an international leader within many research fields pertaining to the production of ores, ballasts and minerals.

For MinBaS industries with its focus on open-pit mining, dry processes and a diversified market for production, often specialized in civil engineering, one has had a need for a very large number of different research skills in order to conduct the R & D collaboration. The needs within production development and product development differ from one MinBaS so the industry to another; the production of natural stone is specific. This also applies with regard to ore production at the mines, but there certain unit processes within breaking, fragmenting, grading and separation processes intersect. Some projects must therefore be conducted as being specific to certain sub-industries and with other research groups than those that have been central to Luleå University of Technology, specialized in problems facing the mining industry.

This has entailed research groups at Chalmers, highly specialized in the development of crushing and grading technology for ballast, industry minerals and ore minerals and the Cement and Concrete Institute / SP with specialists within both natural stone and in ballast constituting important cooperative partners. Umeå University with experts within quickening technology is important to the development within the sector of cement and quicklime. Lund University with its expertise in limestone geology has been a natural part of the lime industry. SLU, Alnarp with its focus on landscape architecture is important to product and application development within the natural stone industry. Even at the Royal Institute of Technology in Stockholm there has been a considerable cooperation with the ballast industry within the civil engineering sector; at the Royal Institute of Technology there is also expertise in water purification, which has driven the cooperation with the MinBaS industries, as these sectors provide filter materials to the water purification side. The lime industry has a close cooperation with the steel industry's research institute, MEFOS, for the development of flux and other admixture products for the iron and steel

processes. At the Luleå University of Technology (LTU), the cooperation has been conducted primarily with experts within blasting technology and concrete production. Previously, there was also a comprehensive cooperation within the mineral technology field at LTU, where it primarily dealt with processes for fine grinding, grading and separation processes aimed at industrial minerals. Within projects currently underway as listed below, there are further examples of research groups that work together with the MinBaS industries.

Ongoing interdisciplinary R & D work

R & D undertakings, many of them with state financing, that involve the MinBaS group:

- At present, two large cooperative projects are underway within Vinnova's efforts in Development-driven Innovation with several of the interested parties within MinBaS Innovation's agenda. These projects already plan a continuation with so-called C-projects with application for this in the autumn of 2014. MinBaS AB conducts in cooperation with producers of ballast, industrial minerals and concrete manufacturers as well as machinery manufacturers, authorities such as the SGU and the Swedish Transport Administration and research institutions such as Chalmers, SLU, Roctim a so-called B project called Uthållig produktion av finkorniga produkter från bergmaterial (Sustainable production of fine-grain products from ballast) with Magnus Evertsson, Chalmers, as project manager. The natural stone industry along with producers of ballast and cement and concrete products, research groups (CBI, SP, SLU, JTO, Stenforsk etc.) as well as cities and municipalities (Stockholm and Malmö road departments) are involved in the UDI B-project named Grå-gröna systemlösningar för hållbara städer (Grey-green system solutions for sustainable cities), with CBI, Björn Schouenborg as the beneficiary of funds and project manager.
- Portions of these groups also have submitted applications for the start of new so-called A-projects within Vinnova's UDI effort in 2013. SLU, landscape architecture together with the stone industry, CBI and cities and municipalities apply for a new A-project named Nya system för sten- och plattytor för hållbart stadsbyggande (New systems for stone and flat surfaces for sustainable city construction). Chalmers, now in cooperation with machinery suppliers (Metso, Atlas Copco, Outotec etc.) and the mining industry, apply for the A-project Energieffektiv sönderdelning (Energy efficient fragmenting).
- As well, two PhD projects are underway at Chalmers pertaining to the development of crushing and grading techniques, which are supported by the industry and industrial foundations. At present, industrial foundations support the project in cooperation with the MinBaS group, SBUF. The construction industries development fund and the so-called Hesselmanska fund, a family foundation, which supports research aimed at the development of machinery for the mining and mineral industry.
- Within the industrial mineral industry, two industrial PhD projects are underway at Umeå, aimed at the development of the oxy-combustion technique and CO_2 separation through mineral carbonization as well as the development of simulation tools in order to facilitate the implementation of alternative fuels in the cement and lime industry. A related, Mistra-financed project Slagg to Cement/Increased use of by-products and wastes from the steel industry in cement production is underway at Umeå University with the cement industry as well as cooperation with the iron and steel industry's residual product company, Merox. The cement industry is also taking part in the Vinnova-financed project called Algodling hos massa- och pappersbruk för hållbar produktion av bioolja (Algae cultivation in pulp and paper mills for sustainable production of bio-oil) which is being conducted with SP as the project manager in cooperation with the pulp and paper industry and chemical companies.
- The cement and lime companies are participating the a cooperative effort with the steel industry, the petrochemical industry and the power industry in a project led by Elforsk called Bastor II, which is financed by the energy authority. The purpose of the project to assess the possibilities for storing CO_2 in aquifers in the Baltic Sea; this is expected to continue with an application in 2014 for a third stage.

Ongoing international cooperation

Below is a list of some of the cooperative efforts currently underway within the EU and internationally:

- **ETP SMR** (European Technology Platform Sustainable Mineral Resources). MinFo as a representative of the MinBaS group has participated for many years in this industry-led cooperative body at the EU level where they are now developing a strategic research and innovation agenda. They also plan to work together with other groups and apply to form a so-called **KIC** (Knowledge and Innovation Communities) for **Raw Materials** within the framework of the European Institute of Innovation and Technology (EIT) investment in innovation-supporting activities.
- **ERA -MIN** (European Research Area – Minerals): MinFo as a representative for the MinBaS group participates in this arena that works for the coordination of research between member states within the mineral field with major support from VINNOVA, SGU and CBI.
- **EIP** (European Innovation Partnership on Raw Materials). A collaboration on the European level with all interested parties (EU, member states, industry, academia and research institutes). Pertains to research, innovation, training and legislation all along the entire value chain, including recycling. Excellent

contacts within the construction sector are established via **ECTP** (European Construction Technology Platform).

- At the EU level, the ballast industry cooperates with its European industry association, **UEPG**, in matters concerning standardization.
- The natural stone industry cooperates on the EU level with its European industry association, **Euroroc**, and conducts cooperative projects within training and LCA for natural stone. Stone companies also take part in the EU project known as Hydrasplit which is headed by CBI/SP.
- CBI participates in Euroroc's expert group (Natural Stone Workshop) for activities associated with standardization
- CBI represents Swedish in all work groups within **CEN TC 246 Natural Stone**
- CBI holds the presidency of the **IAEG's** (International Association of Engineering Geologists and the Environment) technical committee **C10 Natural stone**
- Cementa and several of the lime companies, such as Nordkalk and Omya are part of international conglomerates and have a strong cooperation internally within their groups in research and development. Cementa also takes part via the parent company in a comprehensive European research program with the CCS field within the framework for **ECRA** (European Cement Research Academy), in which 40 cement producers take part. Nordkalk takes part in the research collaboration within the Finnish program known as **CLEEN** (Cluster for Energy and Environment) CCS program.
- The cement and concrete industry also have a collaboration within the Norwegian **COIN** program which works inter alia with problems concerning crushed ballast.
- The research groups within MinBaS Innovation have a comprehensive research cooperation both at the EU and international levels. CBI/SP conducts EU projects within the fields of cement, concrete and natural stone. Chalmers participates in the international mining industry's program within the AMIRA research body.
- Machinery suppliers and goods suppliers often are part of large groups of companies and conduct R & D work in cooperation with customers on an international basis.

Why is Sweden particularly strong in this field

Swedish rock is not just strong in a geological and literal sense. It is also one of the countries important strong points. It contains valuable minerals for industrial processes and for building and construction enterprises. Around it, an outstanding extraction industry has been developed, and so has a manufacturing of world-leading equipment for ballast processing. There is potential for increased export of block stone and ballast.

At present, there are no technical or economical alternatives to ballast and industrial minerals in their applications. Ballast is constantly needed for the infrastructure and its maintenance; industrial minerals are supplied inter alia to the cement and lime industry as well as to the steel industry. Natural stone is a building material with a low impact on the environment that has an unsurpassed durability and great aesthetic value.

As well, a long-lasting cooperation between machinery manufacturers, research and industry has been established. This relationship provides the country with a sustainable advantage in the face of international competition, if it is handled correctly.

Below is a summary of the more important factors which show the potential of achieving competitiveness and growth.

- Research of an international class within production techniques and product development
- Significant knowledge and experience within manufacturing companies
- Leading manufacturer of machine equipment and products for rock extraction and refinement. Our hard rock has resulted in the development of robust products

- Knowledgeable consultants within rock engineering and quarry and mineral technology
- Short and informal contact routes between industry, suppliers and research / development. The small size of Sweden can be considered a strength
- The branches' awareness in environmental issues including energy economy.
- Well trained and highly flexible staff
- Experience from working in multi-year-long development programs with support from the state.

National focus and expertise in an international context - Example

Below are some examples of some of the areas that are included in the agenda, where considerable development is going on and where methods and systems are about to be introduced onto the market.

Real-time optimization of crushing facilities is the result of a long development effort at Chalmers, where the governing of the crushing process takes place instantaneously and after the measuring of the results in real time. The work has been conducted conscientiously for a period of 10 years as a number of PhD projects in close cooperation with industrial companies.

Now there is a total of 8 Swedish crushers equipped with this control system. This entails inter alia a continuous RPM adjustment, which is a technical leap forward in the crushing industry. Increased production has been demonstrated and possible channeling toward desired fractions. Furthermore, the wear and tear of the abrasion resistant steel in the crushers have decreased. All in all, this provides opportunities for industry to reduce its need for energy and other resources likely by 5 – 15% (varies according to application). A company has been formed in order further to develop the control system. This is where several good examples are needed, which show the possibilities under various production conditions, i.e., demonstration facilities that take the results to the innovation stage. The potential for exportation of Swedish expert technology in this field is considerable.

The transition from natural gravel to crushed material in the manufacture of concrete One the project was complete, a large number of materials has been tested and one now knows principally what is important to achieve when manufacturing resource-efficient concrete with wholly crushed material. Comprehensive training courses have been held in order to disseminate the knowledge in the industry and program software for the optimization of concrete recipes has been developed. In connection with this, new production methods have also been introduced in Sweden with a so-called dry grading of fine material.

The larger aggregate manufacturers undertake tests at the industry in order to the alternative crushing processes for adaptation to the needs of the concrete (VSI aggregate, cubing equipment etc.) The project has received a follow-up in a Vinnova-supported UDI project in which a further development is done for a full-scale text and an introduction to the result.

Continued efforts for the implementation of the new production technique and efforts for an increased acceptance for aggregate material in varies fields of use contribute to the Swedish environmental goals of a gradual phasing out

natural gravel more quickly can be realized.

Characterization of the rock microstructure and connection to material function and its mechanical properties. Over a period of 15 years, CBI/SP has acquired an expertise which the field of characterizing the properties of the quarries material as associated with their function in various products such as ballast and natural stone. The identification of critical microstructures which are quantified with the help of computerized image processing have to contribute to an increased understanding for the geological processes for the rock's usefulness for various products. Among the examples is Urban Åkesson, who in his doctoral thesis demonstrated the connection between the microstructure of granite and its fragmentation properties in the Los Angeles test. Furthermore, the microstructure of marble could be quantified and used as a criterion for the selection of marble appropriate for outdoor use. A new European standard is based on this method. By quantifying critical microstructures, combined with laboratory experiments, it has proved to be possible to simulate how the rock behaves when subjected to various types of loads. The expertise should be further developed for more properties, types of rock and application. The technique can increase the efficiency in connection with the choice of crushing technique depending on the type of rock. Furthermore, the opportunities are great for being able to simulate the product's function in entire constructions and in that way to optimize the choice of material and quantity for a more resource-efficient construction.

The natural stone industry's interaction with academia within landscape architecture. The natural stone industry has, through its involvement in the MinBaS programs, received its first professorial chair at SLU focused on the use of stone materials both in construction and in landscape architecture. Here there is now a platform for further work with natural stone research and training in connection with a landscape engineer's education. One deals with everything from raw material supplies to production, installation, maintenance and training of future architects and engineers.

The stone industry is conducting a collaborative interdisciplinary UDI project aimed at the development of new systems and methods for the design of future cities where ground coverings with concrete platforms and natural stone come to together with trees and other vegetation. This counters the risk of floods due to climate change. Further development in stabilizing ground coverings is planned. The project mentioned affects those areas in which municipalities and property owners each year spend a lot of money on maintenance. With the right design of modern ground covering systems, this can be minimized.

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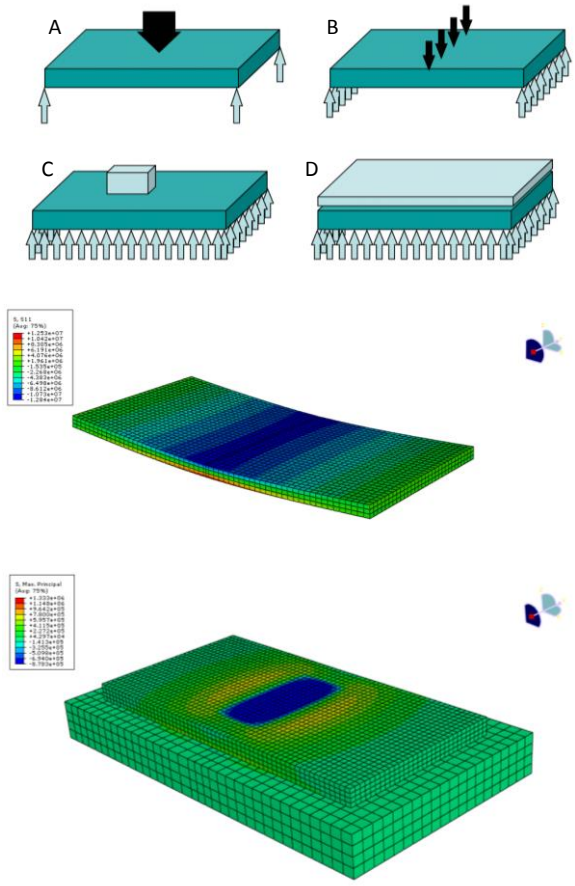
Energy saving and reduced CO_2 emissions within the cement and lime industries. Within the framework of the MinFo project package with the energy authority, there is a unique cooperation between Cementa and Nordkalk within a multi-year research project aimed at reducing energy consumption and reducing CO_2 emissions in the quickening process in the manufacture of cement and quicklime. Two industry PhD from each company have worked at Umeå University with methods and system development in order to implement a more energy-efficient oxy-combustion technique, increase the use of alternative fuels and develop more energy effective CCS (Carbon Capture & Storage) techniques than those currently found on the market.

A software program has been developed which allows for simulations of the combustion processes for various types of fuel, which led to an increased use within the cement industry of alternative fuels, and to the lime industry being able to start such use.
The development of the oxy-combustion technique for the cement and lime industry and new methods for CCS has led to promising results and the focus on development has increased within the fields. The development is now conducted as an international collaboration, a test facility for new, more efficient CCS techniques is, for example, under construction in one of Cementa's Norwegian facilities. On a Swedish basis, the project has begun as a cross-industry collaboration concerning storage possibilities for CO_2 in the Baltic Sea; this is a cooperation between the cement and lime industry, the steel industry, power producers and the petrochemical industry.
Another cooperative project within the lime industry that has been conducted at Lund University has developed methods and systems for predicting the combustion property of various kinds of limestone, which lead to one being able to control production better and yield a reduced fragmentation in the quickening process, which has the potential of providing considerable energy savings.
A substantially reduced energy consumption and reduced CO_2 emissions is a great benefit to the industry and to society, and it is important that conditions be given in order to develop demonstration facilities and for further implementation of the developed processes and systems in industry.

Benefit to society

Society will feel the effects of a carried out agenda, both of an economic nature and of an environmental nature, not to mention the improved knowledge that can be expected.

- A safe and long-term supply of indigenous products, which are needed for society to function
- Resource efficient production, lower quantities of waste, products with long lifetimes, increased recycling results in lower energy requirements and thereby lower levels of greenhouse gas emissions. One comes closer to the environmental goals and the energy policy goals.
- The goal in securing all natural gravel of the need for water supply can be met
- Reduced disturbance in the form of vibrations, noise dust, and an optimal land use, which means greater acceptance from those living in the vicinity and more attractive workplaces.
- Reduced transportation work from heavy volumes by means of the best localization, good planning and a transition from road traffic to other alternatives wherever possible and rational.
- New work opportunities at large, but also small and medium-sized companies.
- Easier internationalization through the industries' and the authorities' contacts



- The geological knowledge and information is used so that important community decisions can be made using the correct basic information
- The geological knowledge is used so that the right quantity can be used in a manner that best makes use of resources
- Innovation systems are developed in the community, where MinBaS industries and their partners are involved
- Recruiting and training of new employees is facilitated and diversity issues can be highlighted in a natural way

Energy relevance

Many of the efforts that are ongoing and which are planned within the MinBaS Innovation agenda are very relevant in terms of energy Within the field of production processes, the following ongoing and planned efforts aimed at energy savings and reduced emissions of CO_2 either directly in the processes and/or indirectly through a better use of resources though reduced quantities of residual materials and increased product exchange.

- The project within the cement and lime industries are very energy-relevant and have a focus on reducing CO_2 emissions and concentrate on making the quicken process more efficient by implementing oxy-combustions and an increased use of alternative, carbon-dioxide neutral fuels as well as the development of separation techniques for CO_2 which are expected to have a considerable lower energy consumption than the Best Practice techniques used today.

Furthermore, careful product planning shall reduce fragmentation losses and improve the product quality in the lime quickening process, while will yield a considerably reduced energy consumption and thereby a corresponding drop in CO_2 emissions.

- The project within the optimization of the crushing and grading processes are aimed at reducing the use of electrical energy in the production of fine-grain ballast and ore minerals through improved process control and PRM control of the crushers.
- The project aimed toward both internal transports and external material transports intend to reduce the use of vehicle fuel (diesel) through and optimization of the transport routes and also to find alternative transport solutions using vehicles or other systems that do not run on carbon-based fuel, which reduces consumption and lowers CO_s emissions.
- The project involving testing and evaluation of new production techniques for breaking and better production planning within the natural stone industry aims at using wire sawing as a general method at several stages of production, which is expected to result in a lower energy consumption as well as an improved exchange in the production.
- The planned project involving life-cycle analysis of both production and product manufacturing gives us a good tool for the assessment of energy loads and contributes to an increased awareness in the industry as to where there is room for improvement.

IMPLEMENTATION

Involved parties

Behind this agenda there is an already well-established collaborating group in the form of three organization, Sveriges Bergmaterialindustri- SBMI, Föreningen Mineralteknisk Forskning - MinFo, and Stenindustrins Forskningsinstitut - Stenforsk and their member companies (ballasts natural stone and industrial mineral producers, machinery manufacturers, material and service suppliers, consultants) as well as a network of research groups at the universities, colleges and instituted and a number of official bodies such as the Swedish Geological Survey (SGU) and customers within the segments where the collaboration is currently conducted.

The network entails some 150 companies and organizations interacting with some 15 research groups. Appendix 2 shows the network under MinBaS II. All organizations that have participated in MinBaS II have expressed interest in continued cooperation.

The results of MinBaS I and II have been evaluated and have also formed the basis for an academic research project on emerging innovation systems (Frykfors 2010).

The MinBaS group has extensive experience in cooperation between industry and academia, and has conducted a large number of collective R & D development projects and programs with state support and with considerable financing from industry. The interaction across industry boundaries is a pillar of the MinBaS formation. A number of collaborative projects have also be carried out over the course of the years with other sectors of Swedish industry, such as the multi-year Vinnova-supported MiMER Metals and Minerals Recycling program that was conducted at Luleå University of Technology that focused on residual products from mining, iron and steel, and the industrial mineral industries, with co-generation plants within Värmeforsk's major project concerning Askor and with power producers, mining, steel and petrochemical industries in Elforsks program pertaining to Carbon Capture & Storage.

The group has an organization set up for research collaboration through a jointly owned research company, MinBaS AB, with an office and coordinators. Two major industrial programs, MinBaS I and II, involving all three sub-industries have been implemented in 2003-2005 and 2007-2010 with state co-financing via SGU. Parallel to that, two project packages with the support of the energy authority have been implemented within MinFo between the years of 2002-2004 and 2007-2010; the latter mainly targeted toward the industrial mineral sector.

For the MinBaS II program, an evaluation was held in 2011 which showed that the program had good qualities, high additionality with respect to state funds and a continuation was recommended as it was considered to form the basis of an emerging innovation system. The corresponding evaluation of the project package from the energy authority, which was ready by the beginning of 2013, shows that the project has, by and large, a high degree of industry relevance, scientific quality, knowledge dissemination and a great potential meeting energy targets.

The actual work with the agenda during the period of September 2012 – March 2013 has consisted of the project management gathering interested parties within the industry and researchers to workshops and industry-specific work groups. At a large number of meetings, these workgroups have analyzed the challenges facing the industry today and challenges that are known that will arise in the future, they have set targets for research and innovation work as well as prioritized measures that need to be implemented in order to attain the set goals. Partners and network for cooperation have also been identified. Both previously prepared project suggestions and R & I activities underway currently have been incorporated into the basic data.

For the compilation of the agenda, and editorial group consisting of the project manager and some 10 other representatives for industry in the three sub-branches, large & small companies, and representative for research groups are responsible.

A cohesive SIO program for implementing the agenda

In order to realize the ambitions in the agenda, long-term financing is needed (4-10 years) that will allow the industries and other interest parties to have a chance to plan, carry out and implement the changes, which are important to industry and society. The program extends across the entire process chain from extraction to recycling and even contains special efforts in

energy and environmental technology, as well as safety. It is about optimizing the entire process chain and in working parallel with environmental and cultural issues. Naturally, priority must be given to those parts having the greatest effect on society and in industry. Programmed diagrams can be found as an annex. The purpose is to:

- Use the knowledge from earlier industry development programs
- Continue the ongoing research and development
- Create some new directions
- Work with innovation and application of results

Develop cooperation with other agendas and other parties in the community

Forms of interaction – other agendas, universities and authorities

There are more possibilities for cooperation with SIO Metallic minerals. The mineral field therefore intends to cooperate with SIO Metalliska mineral in various project and even investigate if it is possible to combine both fields into one common area for the mineral and mining industry. This combination will in such a case come about later for practical reasons.

Mining industry

The challenges identified as being common within MinBaS industries also apply to the mining industry, i.e., sustainable supply of quarry-based products to the community, competitiveness and implementation, provision of skills, increased international exchange and challenges in the form of energy policy goals. Below are examples of conceivable areas of cooperation between the MinBaS group and the mining industry, where there is a need of input in the form of research and innovation-supporting investments. The development project is prepared by mutual collaboration primarily with CTH and LuTH.

- Automation and process control
- Safe and resource-efficient production
  - Effective fragmenting: drilling and blasting
  - Energy-efficient loading and transport
  - Energy-efficient disintegration: crushing and grinding
  - Efficient sifting and grading
- Permit processes
- Attractive workplaces – safe and healthy
- Environmentally friendly technology – Outer environment / Working environment
- European cooperation

Steel industry

Some of the challenges identified as being common within MinBaS industries also apply in part to the steel industry, i.e., competitiveness and implementation, provision of skills, increased international exchange and challenges primarily in the form of energy policy goals. Below are examples of conceivable areas of cooperation between the MinBaS group and the steel industry, where there is a need of input in the form of research and innovation-supporting investments.

- Lime product in the iron and steel processes
- The use of the iron and steel industry's residual products in cement-bound products and in road construction.
- Development of energy efficient CCS systems

Infrastructure

Contacts and meetings / seminars where project management participated have been held in order further to develop ideas for interaction in project form with two agendas within civil engineering:

- GIMI -Green Infrastructure Material Innovations Program Development, which is a collaboration between various KTH platforms focused on materials and traffic and where companies within the MinBaS network already are involved as interested parties. Project collaboration for the development of "green" construction materials have been discussed.
- IQ Samhällsbyggnad in order further to develop project cooperation within, for example, planning of the supply of raw material and documentation of the material flow and use. The network shall be expanded with more involvement from official agencies, e.g., the Swedish Transport Administration. Specialist expertise within road construction shall be added to the network, for example, VTI.

How existing resources and infrastructures can be more cleverly utilized

Many projects in the future SIO program from MinBaS aim to use quarried raw materials more efficiently. In the program cluster "Product development for civil engineering and infrastructure", it is intended, for example, that the project called "Recycling processes – impetus and regulation" increase the recycling of ballasts in concrete and asphalt as well as rock that has been broken in the contracted project. This shall reduce the need for extracting new rock.

Through better coordination of the various processes in the value chain, prospecting – breaking – processing – delivery of ballast and other minerals, a better use of the material can be accomplished and less production resources [above all energy] needs to be used during shorter lead times.

By developing the transport system in which, for example, optimal roads with respect to distance weather, congestions, fuel costs, driver time and any tolls are calculated, the transport costs can be reduced. If, moreover, environmentally customized vehicles are used, these can also be used in the future where there are obstacles to transports that upset the environment.

At present, secondary ballast is recycled from concrete, asphalt and contractor activity as well as other materials seldom in the same place as a new quarry is broken and processed. This entails unnecessary transports and poor utilization of the ground. By planning and setting up facilities for production and recycling together, transports can be reduces and the ground can be put to better use.

Administration

Working method and organization

Within MinBaS AB there is a proven model for how the work is conducted at various levels in the program in order to increase the involvement of the participants according to the following:

The overall responsibility and management lies with a program management.

In the program management, one will primarily find representatives of industry with a long experience and good familiarity with research and development matters and the industry's needs are represented in various sub-industries within MinBaS Innovation. The program management is divided into work groups with responsibility for specific program fields; these work groups may call-in experts if needed.

The day-to-day management with program administration, program management and follow up is the responsibility of one of the members of the program administration appointed as program secretary.

At the program field level, a control group is appointed consisting of representatives from companies, research groups, official agencies etc. that are active in the projects run within the program field. They are responsible for following up on program work toward the goals, vision and strategy within a given budget that the accounting shall be done according to contract and to recommend changes in the project plan and initiate new projects.

For larger single projects, project work groups with representatives from the participating companies and research groups are appointed to help those conducting the research. They are responsible for following up on program work toward the goals, vision and strategy within a given budget that the accounting shall be done according to contract and to recommend changes in the project plan and initiate new projects.

Innovation process

MinBaS Innovation will work within an "innovation system under construction" in order to attain the goals of sustainable development, skills development and competitiveness. The renewal process, also called the innovation process that has gone on for nearly 20 years within ballasts, industrial minerals and the natural stone industry (Frykfors & Klofsten 2010) have now reached a level where they can perceive the emergence of a fully developed innovation system. The involvement of industry has gradually increased.

A few main areas, some specific to each branch of industry, others common to all three, have materialized as being the most prioritized in the common development work. They have been run from MinBaS I via MinBaS II and STEM programs and the result from research and development work shall now be transported to MinBaS Innovation in the form of demo projects and/or be marketed/applied together with customers. Other areas have shown to require continued development work. New challenges have arisen that indicate a need for continued technical development work.

Through MinBaS Innovation, the possibilities are greatly improved for the knowledge that has gradually been acquired in earlier research programs such as MinBaS I and II to approach a broad implementation in the industry by users and society. The speed of the innovation process can be increased using the working method indicated within the MinBaS Innovation agenda.

APPENDICES

Appendix 1 – About the industries

Ballast

Ballast, i.e., rock aggregate, sand and gravel, are used for building and construction purposes. Ballast is an indispensable local Swedish commodity. It is necessary for a functioning infrastructure in the form of roads, railways, harbors and airports and thereby for the development of industry and employment. It is also needed for the construction of industrial premises, residential buildings, offices, hospitals and other official buildings and thus in general for human health and well-being. The greatest area of application is in the construction of roads, where the material is used both in the substance of the road and in the surface layer. A well-built infrastructure facilitates environmentally friendly transportation and thereby the competitiveness of industry. The material is also used in railway embankments, ground-levelling and as an ingredient in concrete and asphalt, in which constitutes approximately 80 and 90 percent of the content, respectively. In total, 90 million tons of ballast is produces and delivered every year. This makes ballast the most important product by weight. The value of the annual production is approximately 6 billion in the pits and about 9 billion Swedish crowns after being delivered to location of use. The ballast industry employs approximately 6000 people.

Natural stone

Sweden has a bedrock that is old and in some respects unique. Swedish natural stone is highly prestigious among the world's natural stone consumers due to its very good technical qualities and appearance in combination with the careful quality controls in production. The most common areas of use for natural stone are paving (streets, squares, roundabouts and garage ramps), walls, building facades, roofs, stairwells, floors, countertops, gravestones and works of art. 85% of the block stone production is exported to markets worldwide. Secondary material is used by the ballast industry for building and construction purposes such as aggregate products and sea stones. The value of the year's production is approximately SEK 1.3 billion in pits and factories; the value after delivery to the location of use and finished goods is considerably greater since the industry supplies a large portion of raw blocks and semi-finished products. The value of the assembly side is added extra, as a large part of the assembly is done by companies related to other industries, such as the construction industry. There are approximately 1200 people employed in the stone industry.

Industrial minerals

Crushed lime, an ingredient in quick lime and cement, is ton for ton the most significant industrial mineral. Yearly production was approximately 7 million tons in 2010 of which approximately 4 million tons went to the production of cement. Gotland is the most important region of production of limestone. The value of the annual production is approximately 2 billion Swedish crowns. The industrial mineral sector employs roughly 2,000 people.
Cement is principally used in concrete, which is one of the most important construction materials for the construction and building industry (the building of houses, bridges, tunnels, roads and railways, dams, water and drainage systems). Without concrete construction, it is not possible to construct the society of the future with energy-efficient houses, infrastructure that enables energy-efficient transportation and a guaranteed, secured supply of electricity and water. The production of cement in Swedish is just over 3.2 million tons. Approximately 0.8 million tons of production is exported and approximately 0.45 million tons were imported.
Ground and quickened lime products have very broad range of uses in our society**.** There are currently no alternative material which technically and economically can replace lime production in industrial processes. Quickened lime products find their largest markets within the iron and steel industry, and in the pulp and paper industry where they make up a vital filler material. They also have a place in the building and construction industry, in the filtering of flue gases, water purification and in the chemical sector. Ground lime and dolomite products also have an equally large field of use, but in addition they are also used in agriculture and in the liming of lakes.

Appendix 2 – Participants within MinBaS – the network

Aros Mineral AB
Bergsskolan
Betongindustri AB
Bioptech AB
Björka Mineral AB/Omya AB
Bohusläns Kooperativa Stenindustri AB
CBI Betonginstitutet AB, (SP) Borås
CBI Betonginstitutet AB, Stockholm
Cementa AB
Chalmers tekniska högskola, Inst. f Produkt och Produktionsutveckling
Emmaboda Granit AB
Hallinden Granit AB
KTH, Mark& Vattenteknik
Metso Minerals(Sala)AB
Misec AB
NCC Roads AB
NCC Roads, Väst
NCC Teknik
Nordkalk AB
Nordkalk AB, Storugns
Nordkalk Abp,Pargas
Nordkalk Köping
North Cape Minerals AS
Orica
Sand & Grus AB Jehanders
Sandvik Mining & Construction
SBUF
SBMI
SMA Mineral AB
SKANSKA
SSAB Merox AB
Sveriges Geologiska Undersökning (SGU)
Stenindind. Forskningsinst. AB
Sv. Vanadin AB
SWEBREC
Swerock AB
Bohusläns Koop. Stenindustri
Borghamns Natursten
Borghamns Stenförädling
Emmaboda Granit AB Göinge Utbildningscenter
Jananders Consulting
Lennart Selrot Marknadskonsult
Marmor&Granit AB
Naturstenskompaniet
SFI AB
Sjöstöms Stenförädling AB
SLU
CBI Betonginsitutet AB, (SP) Borås
Stenmontering Hässleholm
Stenrådgivning
Stenutveckling Nordiska AB
Thorsbergs Stenhuggeri AB
Triotensid AB
Zaar Granit AB

Once MinBaS had started, a few new interest parties were also added via their trade associations, (for example, Skanska, Bergsprängningsentreprenörernas Förening).