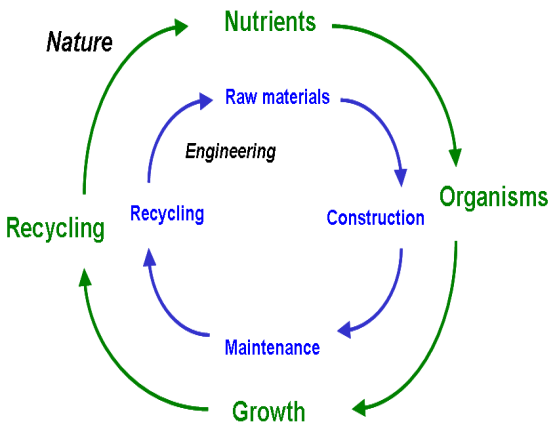
Final Program

STW Perspectief Program

Bio-Based Geo & Civil Engineering for a Sustainable Society

(BioGeoCivil)

January 2010



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Bio-Based Geo & Civil Engineering for a Sustainable Society

BioGeoCivil

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Summary

Objectives

The program Bio-Based Geo & Civil Engineering for a Sustainable Society (BioGeoCivil) aims to revolutionize the manufacturing and application of materials and products used in geo and civil construction. Currently, geo and civil engineering produce vast amounts of waste, not only at the end of the life-cycle (e.g. as construction and demolition waste), but also in the beginning where the materials are designed and made. Using biological processes to design upgrades of raw materials, reduce waste production, to convert low grade waste materials to high value and sustainable resources in construction, as well as to enhance the beneficial re-use of resources in high quality applications, are major challenges that will have a profound impact on the sustainability of society.

The challenge of this BioGeoCivil program is to develop biology-based materials, technology and processes that solve engineering challenges addressing sustainable performance (in terms of resource depletion and required functionalities related to strength, permeability, climate control, air quality improvement and more), while at the same time reducing the impact on the environment compared to traditional solutions.

Focus

This program aims to bring researchers from geo- and civil engineering and biology together with industrial partners and stakeholders in order to utilize bio-based technology or materials for a wide range of applications. The four major application fields are the major elements of the building cycle as can be seen in figure 1:

1. Production of (raw) materials;
2. Construction;
3. Maintenance;
4. Upgrading, reduction and recycling of waste materials.

The research in this program should focus on obtaining a deeper insight in how nature (micro-organisms, plants, ecosystems) produces and (re)cycles materials and how nature changes functional characteristics of materials and structures like strength, water retention, noise adsorption, flow and transport of water and chemicals etc. Essential research topics that need to be addressed are:

a. Functional and fundamental properties;
b. Bio-based material functionality;
c. Bio-based material compatibility;
d. Process control;
e. Multi-scale integration;
f. Quantification of sustainability.

Summary of the duration and requested budget

A program duration of 6 years is scheduled during which PhD and Post-doc projects will run almost simultaneously for maximum project integration. The program budget is estimated at 5.2 M€ of which 3.9 M€ is to be provided by STW and 1.3 M€ by the stakeholders. The estimation is that the budget will be distributed among different items; in the order of 65% to manpower, 20% equipment, 10% consumables and traveling, and 5% towards valorization.

Introduction

Geo and civil engineering are disciplines that already have a long tradition with sustainability in the sense that many of the structures have been built to last for long periods of time with concomitant implementation of material recycling and alleviation of environmental pressure. However, technological innovations are now required to further mitigate or perhaps even completely remove the pressure from geo and civil engineering activities on the environment. The challenge we face is to develop materials and processes that require less energy, are based on renewable resources, have a lower carbon and environmental foot print, and produce a minimal amount of waste and emissions to soil and groundwater in the complete life cycle of a building or infra-structure. Current concepts such as Ecological Building and Cradle to Cradle, substantially contribute to increased sustainability, and we foresee that the development of novel largely renewable bio-based materials and processes can provide major breakthroughs in more sustainable geo and civil engineering practices.

Example: Resources required for Cement

The process of cement production requires large amounts of natural resources such as limestone, clay and fossil fuels. Although the cement industry has been able to reduce the emissions to the lowest possible levels, cement production accounts presently for 7% of total anthropogenic CO_2 emissions, a value that will increase due to massive application of concrete in upcoming economies. This example clearly indicates that innovative approaches concerted with sustainable cement and binder production processes have to be developed in order to further reduce the CO_2 emissions.

Joining forces with nature has already proven to deliver sustainable engineering solutions. Perhaps the ones best known are biological waste water treatment and in situ remediation of contaminated soils using biological processes. Recent research initiatives at various Dutch scientific institutes show that the idea to use biological materials and processes for the development of innovative and sustainable geo and civil engineering practices is expanding. Examples are: 1) Development of bacteria-based self-healing sustainable **bio-concrete**; 2) Development of 'smart soils', e.g. bacteria-based soil stabilization techniques like **bio-grout**; 3) Application of natural fibers in construction material such as concrete; 4) Promotion of 'living walls', e.g. **green facades** on concrete structures in urban areas for improvement of well-being and air quality; 5) Development of bio-based coatings for conservation of structures and building materials; 6) Development of bio-inspired techniques to combat fine dust and mist; 7) Stimulation of biological processes in reducing the impact of micro pollutants on ground- and surface water quality.

At present, most of these concepts are in the initial and exploratory phase. Fundamental questions with respect to the basic principles should be answered before making the step towards large scale implementation/upscaling. Currently the field of bio-based geo and civil engineering is very fragmented, although the experience from the mentioned concepts shows that the fundamental processes underlying the bio-based concepts are very similar.

Objectives

The challenge of this BioGeoCivil program is to develop biology-based materials, technology and processes that solve engineering challenges addressing sustainable performance (in terms of resource depletion and required functionalities related to strength, permeability, climate control, air quality improvement and more), while at the same time reducing the impact on the environment compared to traditional solutions. Figure 1 illustrates the starting point of the program: engineered applications go through a cycle, similar to the circle of life, but nature is far more balanced as production and maintenance processes are more efficient and often no waste is produced due to

symbiotic recycling. With this STW-program we want to stimulate the cooperation between researchers from the civil & geo engineering disciplines and researchers from the biological sciences in order to develop new biology-based solutions to engineering challenges.

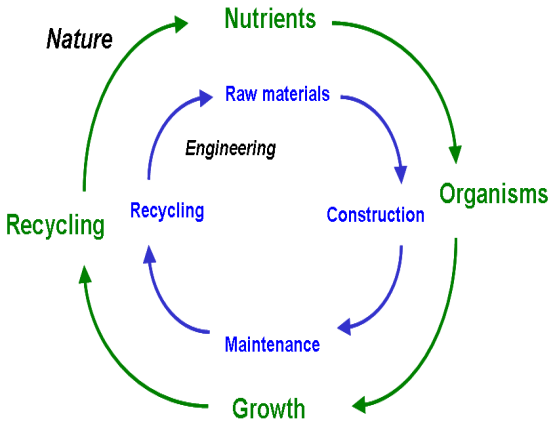

Figure 1: Comparison of the building cycle with the life cycle in nature

This program will bring the, until now, fragmented research field of bio-based geo and civil engineering together in one program, strengthening the research body and allowing for pre-competitive collaboration that solves common fundamental issues which currently limit application of the bio-based concepts.

Researchers from different disciplines are challenged to work together to find answers to a number of fundamental questions that are generic for all elements in the building cycle and which are essential for further development of bio-based concepts towards innovations that can implemented in the field of geo and civil engineering. It is expected that this knowledge significantly shortens the development cycle of the currently explored concepts mentioned earlier. In addition the increased collaboration together with more knowledge provides a stimulus for a whole new range of concepts.

In order to achieve this goal we have defined the following objectives:

1. Increase our fundamental knowledge of mechanisms nature uses to solve construction and functionality challenges we face in the field of geo and civil engineering;
2. Develop robust biology-based technology, methods and processes that enable improved functionality and reduced environmental burden in geo and civil engineering applications;
3. Define and demonstrate the requirements for upscaling; application of these findings in materials and processes in geo and civil engineering;
4. Create a Dutch knowledge-platform of bio-based geo and civil engineering, combining representatives from research and industry, that enables the development of a strong research and economic infrastructure focused on sustainable geo and civil engineering.

Key Application Fields

The four **key application fields** in this program are the major elements of the building cycle, shown in figure 1:

1. Production of (raw) materials;
2. Construction;
3. Maintenance;
4. Upgrading, reduction and recycling of waste materials.

The current bio-based geo and civil engineering projects only target a small part of the building cycle. The goal of this program is to focus on the common fundamental knowledge that is required for all developing bio-based approaches for all elements in the building cycle shown in figure 1. New bio-based building materials will be developed that combine traditional civil engineering properties like strength and durability with different integrated biological functions such as the capacity for self-healing or adaptation to changing environmental conditions. This leads to a substantial improvement of environmental quality in combination with expected large economical benefits.

It is encouraged that (e.g. the agricultural) industry starts to play a role in the production of bio-based building materials such as bio-cement, fibres and plastics. This market is as yet non-existing.

1. Production of (raw) materials

How to produce bulk quantities of bio-based (and thus renewable) resources for (low-end) geo and civil engineering applications?

The field of geo and civil engineering requires a significant amount of resources to enable the production of the required infra-structure. Currently a major portion of these resources comes from non-renewable resources. An example of a natural process that could be utilized in this respect is **Bio-mineralization**, which is the process by which living organisms produce minerals, often to harden or stiffen existing tissues. This process is ubiquitous throughout the living nature: all six taxonomic animal kingdoms contain members that are able to form minerals, and over 60 different minerals have been identified in organisms serving various purposes such as superior material characteristics (nacre in mollusk shells) and sensing behavior (magnetite in magnetotactic bacteria). In addition plants are also able to produce and incorporate minerals in their structure (silicate in bamboo and rice straw).

The concepts that are currently investigated are generally in an initial and exploratory phase and if there are any applications, these are only in high-end situations with very small volumes. In order to make low-end geo and civil engineering applications feasible we need to overcome barriers brought about by the time- and length-scales associated with the relevant bio-based processes.

2. Construction

How can we construct geo and civil infra-structure based on biological material and / or living organisms with improved functionality and durability of geo and civil infrastructure?

Many of the engineering challenges in geo and civil engineering focus on creating suitable mechanical properties for specific applications. An example is building on or in soft soils, which often requires some form of mechanical stabilization. **Bio-grout** is a biology based solution to mechanical stabilization in order to increase soil strength. In bio-grouting, bio-mineralization processes are utilized to cement loose sand grains to each other via the in-situ precipitation of calcium carbonate, however, process control and predicability are still very difficult to achieve.

Other concepts in this domain are the utilization of plants integrated with buildings and infrastructure (in so-called **green facades**) to improve local climate and air quality in cities or utilization of biological fibers in concrete for reinforcement. These examples indicate how biological materials and even living organisms can increase durability and functional aspects of geo and civil engineering constructions.

3. Maintenance and protection: service life

What are bio-based solutions to reduce maintenance and increase service life?

Maintenance focuses on maintaining the required functionality for long periods of time. **Bio-concrete** is an example of the application of bio-based self-healing where calcium carbonate producing bacteria are mixed with concrete. The bacteria become activated by the presence of water (entering via a crack) and subsequently start to produce calcium carbonate which seals the crack. Self-healing bio-coatings are considered to be bio-based solutions with high potential to prolong the functional life time of infra-structure, and which can result in a significant reduction in resource consumption and therefore to increased sustainability.

4. Upgrading, reduction and recycling of waste materials

How can bio-based solutions reduce waste-production?

One of the key principles of the Cradle to Cradle philosophy is that waste does not occur in nature. All resources used are renewable and the recycling of nutrients and materials is one of the main features in natural processes. For the built-environment this would mean that waste can only be tolerated if it can be re-used as a building material.

Currently, geo and civil engineering produce vast amounts of waste, not only at the end of the life-cycle (e.g. as construction and demolition waste), but also in the beginning where the materials are designed and made. Using biological processes to design upgrades of raw materials, reduce waste production, to convert low grade waste materials to high value and sustainable resources in construction, as well as to enhance the beneficial re-use of resources in high quality applications, are major challenges that will have a profound impact on the sustainability of society. Sustainability criteria to be considered include the minimization of emissions from recycled materials to soil and groundwater in the complete life cycle of a building or infra-structure.

The illustration in figure 1 shows the building cycle as a closed loop. The Cradle to Cradle philosophy claims waste to be a concept from the "old way of thinking". Closure of cycles and considering "end of life" in the development stage are essential concepts for sustainability. Bio-based concepts for geo and civil engineering will be important for closing the building cycle.

Research topics

The research in this program should focus on obtaining a deeper insight in how nature (micro-organisms, plants, ecosystems) produces and (re)cycles materials and how nature changes functional characteristics of materials and structures like strength, water retention, noise adsorption, flow and transport of water and chemicals etc. The aim is to harness this knowledge for enhancing the development of innovative applications in geo and civil engineering. Essential research topics that need to be addressed are:

a. **Functional and fundamental properties:** Key to the successful implementation of bio-based concepts is the understanding of underlying mechanisms. What is current state-of-the-art knowledge, what is still largely unknown and needs to be resolved for practical application? The scientific challenge is to obtain a deeper insight into how nature (micro-organisms, plants,

animals, and whole ecosystems) changes function characteristics of materials (like strength, water retention, noise absorption, flow and transport of water and chemicals etc.), how materials are (re)cylced and how we can use this insight for the development of innovative applications.

b. **Bio-based material functionality:** How does the newly proposed concept, functionally, replace the currently applied system and to what extent is the new concept superior?
The ambition of this program is to develop new biology-based technology for engineering challenges. Functionally, these solutions should improve the traditional solutions that are currently, used. Furthermore development of adequate measurement and monitoring methods for assessing the quality of achieved results is essential for fast acceptance of these new approaches by the geo and civil engineering field.
A major aspect of biology-based solutions is that the biological system used, has the tendency to adapt to changing conditions. In order for a technology to be accepted as an alternative, we need to show that the basic functionality does not change over time. However, natural change may provide new concepts: growing biofilms may change as the seasons change. Infrastructure with such a biofilm as a protective coating has a specific appearance as each season passes and as the protecting eco-system matures.

c. **Bio-based material compatibility:** Is the proposed biology compatible with the material / construction? How can possible negative aspects be overcome? Biology-based solutions to engineering challenges often require living organisms. A major challenge is to engineer systems in which the required organisms are able to thrive, especially considering the harsh environments associated with the "man-made" infra-structure. The idea is to create optimal conditions for the biological functionality we desire. What is the long-term development of the biological system and is it be robust?
Many of the materials used are porous, many of the biological systems consist of bio-films. Understanding the bio-based material compatibility requires an integration of fundamental knowledge in the field of reactive flow and transport of water and chemicals in porous media and growth and development of biofilms in and on such porous materials related to both biotic and abiotic factors.

d. **Process control:** How can the applied biology be controlled in the short- and long term?
How to utilize living organisms or biological material for the production of CO_2 neutral thus sustainable materials (e.g. cement) in the required volumes? Natural systems possess an enormous variety of capacities to produce materials at low temperature and low pressure conditions in primarily water based systems. Many organisms (algae, plants, foraminifera) are capable of growing structures like shells and skeletons from calcium carbonates and silicon oxides. These organisms can possibly be used for the production of novel materials with improved functionality and durability aspects but with a substantially lower environmental footprint than traditionally produced construction materials. The scientific challenge lies both in how to utilize natural organisms or materials for the production of CO_2 neutral thus sustainable materials (e.g. cement) and in sufficient quantities.
In order to have biology-based solutions to become a success and to achieve a significant reduction in resource consumption and higher sustainability, we need efficient and large-scale processes. The current amount of non-renewable resources consumed by geo and civil engineering is huge. A major question is what type of process can be envisioned that could provide renewable resources in the quantities required by geo and civil engineering? What technology is required to make such a process feasible? What industrial parties would need to be involved to produce these solutions?

e. **Multi-scale integration:** This aspect has two faces: 1) Can the proposed bio-based system be up-scaled for (future) full-scale practical applications? 2) The scale of the biological process is generally much smaller that the scale of application of the bio-based solution. Overcoming this wide range in scales requires significant innovations is scientific approaches. Biology-based engineering requires control of biological processes, measurement and monitoring methods at these different scales and mathematical techniques to model the processes in order to enable predictions about behavior at different scales and in the (far) future. Heterogeneity as well as complexity are important parameters that need to be addressed.

f. **Quantification of sustainability:** The goal of this program is to achieve a significant reduction in ecological foot-print. Several methods exist to quantify this reduction, which is best and what further development is required?
Methods for an objective assessment and comparison of resource and energy consumption, waste production and emissions, are essential for the success of this program. A truly sustainable solution does not transfer the burden to another part of the production cycle. Assessing sustainability is therefore one of the pillars of the BioGeoCivil program. Quantitative assessments of ecological footprint reduction are required for all concepts studied in this program.

The proposed BioGeoCivil program aims to combine expertise from the so far largely unrelated scientific fields of biology, geo-technology and civil engineering, to develop innovative biology-based concepts for (raw) materials, technologies and processes. Other scientific fields are of course essential as well. The program aims to stimulate the development of new knowledge areas on the interface between geo & civil engineering and biology and other disciplines such as physics, biophysics, organic chemistry, geochemistry etc.

Focus, coherence and knowledge transfer

The BioGeoCivil program is an innovative initiative with a significant risk that the program gets lost in exploration without leading to concrete applications. This risk can be significantly reduced by integrating the currently fragmented research field in a single program where the field is challenged to target the collectively shared generic research questions. The focus in this program will be on respectively concepts, materials and processes. Products are concepts that are ready for the market, and as such, products are significantly different from materials. In this program we will not be able to make the step towards product development. The program aims to develop a strong (collective) knowledge base which enables product development (within the building cycle) as spin-off from a STW-project together with industry.

The already existing projects such as Bio-grout and Bio-concrete already show a number of common research questions, which need solving before further development is possible. On the other hand we expect new concepts to be introduced in the program which will broaden and strengthen the range of essential fundamental questions underlying a successful development of a bio-based building cycle. Therefore we see two approaches:

1. Research on fundamental issues limiting the further development of existing concepts. This will bring these concepts a major step towards application and product-development;
2. Research on fundamental issues underlying new concepts. This type of projects will by necessity be more exploratory than the first type.

The projects will be based on engineering challenges formulated by industry. A number of parties has shown interest to participate in a further development of the existing concepts (for example in

collaboration with the "Smart Soils" pilots which are currently being undertaken within Deltares. During the initial workshop of the BioGeoCivil program a number of interesting issues were mentioned (Royal VOPAK, Port of Rotterdam, Dutch Institute for Building Biology and Ecology).

The program committee will closely follow the projects to ensure that the program goals will be met. A yearly workshop will be held, which is compulsory for all participants in the program, to discuss obtained results and to identify the remaining challenges.

The fields of biological waste water treatment and soil contamination remediation are excluded from this program as these are already well established fields. However, the success of both technologies has shown that a strong integration between Civil Engineering disciplines and Biotechnology can lead to successful and innovative new technologies.

Application perspective

Impact and effects

Currently the civil engineering practice is facing important challenges of reducing its environmental impact in the growing global economy. At the same time several large initiatives are being undertaken in different parts of society where we feel that bio-based as well as bio-inspired concepts could be helpful. Examples are:

- 'Biobased Economy' , coordinated by the Dutch Ministry of Agriculture, Nature and Food Quality, focus lies on the use of renewable green resources for the production of chemicals, products, transport fuels and other forms of energy;
- "Nationaal onderzoekprogramma Kennis voor Klimaat" and "Klimaat voor ruimte", coordinated by WUR, UU, VU, KNMI and TNO/Deltares. The programs focus on developing and organizing the knowledge required to make The Netherlands climate proof;
- National program sea and coastal research (ZKO), coordinated by NWO. The ZKO program aims to facilitate collaboration between different research institutes in this field. Research done within this program focuses on strengthening the understanding and knowledge of coastal development, the role of biogeochemical cycles and particle flows in relation to water quality, the capacity for a sustainable yield of the ecosystem, changes in biodiversity, the influence of seas and oceans on climate change and the effects of climate change on the marine system. This understanding can provide a basis for possible predictions.
- CATO-2, the Dutch national Carbon Capture and Storage program. It includes a consortium of nearly 40 partners working together to help realize the governments plans. CATO-2 has an extensive budget and is expected to be running from 2009 until 2014;
- Building with Nature, this program is geared towards the next step in hydraulic engineering: moving away from defensive design approaches with the aim of minimizing negative effects and moving forward to design approaches and designs that target the maximization of system potential. To make the transition to building with nature, a number of fundamental obstacles need to be overcome. We will have to learn what building with nature signifies in terms of decision-making and collaboration with parties involved in the development of infrastructure.
- BE-Basic (Bio-Based Ecologically Balanced Sustainable Industrial Chemistry) focuses on research for the development of biological raw materials such as biochemicals, bioplastics, and biofuels. The impact of the production on the environment is investigated in detail using DNA-technology.

The BioGeoCivil Program and its associated knowledge platform is complementary but can at the same time benefit from these programs. This combined knowledge shall strengthen the Dutch position in the international top of research and engineering. As such the economical prospects of our national civil engineering industry will improve. In addition, new innovative collaborations will develop. It is foreseen that e.g. the agricultural industry will start to play a role in the production of mineral building materials (e.g. bio-cement, fibres and plastics). This market is as yet non-existing.

The BioGeoCivil program aims at developing concepts which will allow the production of biology based building materials that are produced close to the location of their application. Therefore, a significant reduction in transport costs and green house gas emissions can be expected. The development of new infrastructural bio-based materials that combine traditional civil engineering properties like strength and durability with different integrated biological functions will lead to an improved environmental quality.

Interaction between research and users group

A crucial aspect of this program is the close link between knowledge institutes and industries. User group-defined engineering challenges should result in innovative solutions, that after further development by industry, can be brought to the market. The users group for this program is very wide: it consists of building contractors, building material suppliers, algae farming companies, city authorities, town planners, architects, farmers, consultants, etc. After initiating the BioGeoCivil Knowledge Platform within this program, Delft Univeristy of Technology will continue co-ordinating this platform in collaboration with CUR-net in Gouda.

Considering the pre-competitive character of this research, an essential part of the program will be the interaction between the academia, knowledge institutes and interested industry. Besides the user group meetings for each project, we expect to have regular workshops for all parties involved in the program to exchange ideas and identify essential fundamental issues.

Utilization plan

One of the most important aspects for utilization in this program is that the industrial partners in the research consortia formulate the R&D challenges which underlie the projects. These challenges provide the focus for the individual projects.

As was stated in the ambition and goals, an important aim of this program is to develop a Knowledge Platform for bio-based geo and civil engineering which brings together all relevant expertise in The Netherlands. This knowledge platform aims to maintain a network of scientists and practitioners that until now have hardly had any professional interactions. The BioGeoCivil program can link to ongoing programs of Deltares (http://www.deltares.nl/nl/kennis-en-innovatie/onderzoeksprogramma-s), TNO Built Environment and Geosciences , ECN and Alterra (http://www.kennisonline.wur.nl/).

Two annual meetings per project will be organized with a user-committee to be chosen at the start of the project. Each project should be a collaboration between a biology oriented group and a civil/geo engineering group. Each project is expected to produce papers to be published in peer reviewed international scientific journals to contribute to both scientific as well as public acceptance.

In order to increase the impact of the program, we aim to contribute to the translation of results from the research projects into educational material for secondary schools and higher vocational technical schools. It is encouraged that academic participants attract MSc-students to do their thesis

research in the field of BioGeoCivil.

Strategic relevance of the program

This program aims to develop knowledge with which new concepts, materials and processes can be developed that increase the sustainability of civil engineering. Given that western societies (including The Netherlands) are facing enormous challenges such as mobility, urbanization, and adaptation to climate change, which all require solutions from geo and civil engineering, the results from this program are essential for a more sustainable future.

Currently, several groups in The Netherlands have achieved spectacular results with bio-based concepts such as bio-concrete, bio-grout and green facades in small projects. Combining this experience in a single program, and increasing the volume of projects will create a strategic advantage for the involved researchers but also for the Dutch economy. It is foreseen that this program will develop concepts for novel materials and processes which can be put on the national and international market in the future. Integration of all knowledge present will strengthen the Dutch position in the international research and development arena.

The initiatives concerning bio-based geo and civil engineering practices in the built environment are not (inter)nationally coordinated or organized so far. A joint US and UK initiative has started on BioSoils applications: http://www-civ.eng.cam.ac.uk/BioSoil/, contacts with the involved researchers exist because of the international conference on BioGeoCivil organised in Delft in 2008. The BioGeoCivil knowledge platform associated with this national program can act as a principal platform for future international knowledge exchange and collaborations in this field.

Community of interest

On December 10, 2009, a workshop was held with members from the community of interest. Appendix A gives the list of people invited and present at the workshop. Although the topic is relatively new, getting interest from people from a widely diverse background (different sectors of the industry, different research background etc.) was not difficult. This shows that the community of interest is potentially large in The Netherlands.

The BioGeoCivil proposal was well received and was discussed in a very constructive way. Important conclusions from the workshop are that it indeed is a very innovative and new topic, and that (pre-competitive) collaborative exploratory research by biological and civil/geo engineering groups is required and feasible. A very important conclusion from the workshop is that it is essential to link this program to large research programs on bio-based or bio-inspired technologies in others fields which are already ongoing in The Netherlands. Linking the projects to these other programs should be done at the level of projects. During the yearly workshops, experts from the other programs will be invited for special sessions.

Duration, structure of the projects and requested budget

A program duration of 6 years is scheduled to enable the envisioned multi-disciplinary approach. In order to fulfill the program targets a critical mass in the range 15 PhD and 4 Post-doc projects is required to obtain sufficient fundamental knowledge that can be integrated in experimental studies in order to demonstrate the bio-based concepts. This critical mass is also believed to be required to establish the desired internationally acknowledged BioGeoCivil knowledge platform. Each project should be a collaborative effort of at least two PhD-researchers both with a different background, one in the field of geo or civil engineering, the other in the field of in biology and if required other

expertise can be included. Research consortia are encouraged that consist of clearly different research groups.

The role and contribution of the industrial partner(s) is essential for focusing the research towards economically feasible products. Due to the fact that obtained knowledge on all levels needs to be exchanged before successful products can be realized, the program committee will actively stimulate linkages between relevant projects. A budget of 5.2 M€, of which 1.3 M€ provided by the stakeholders is foreseen, and would allow the funding of approximately 7 to 8 of these multi-disciplinary projects. The post-docs are supposed to have an integrative role in the program.

The maximum of project costs that can be requested from STW is € 750.000 per project. A contribution of potential "users" of at least 25% of the total project budget is compulsory and adds up to the requested amount from STW. The users do not have to co-finance up-front in the program but may contribute in-kind (materials, equipment, facilities, etc) and/or financially in the project wherein they will participate.

A total amount of k€ 70 will be reserved for program activities in order to strengthen the BioGeoCivil community. This budget will be used for the organization of the annual workshop, a professional website, and the organization of meetings to coordinate and strengthen collaboration in the program. This funding will be made available by the STW board upon advice of the Program Committee. All other costs for the participating groups should be incorporated in the project budget plan.

Proposals and selection

The selection of proposals will be made in two steps: a call for pre-proposals and a subsequent invitation of selected applicants of pre-proposals to submit full proposals. The pre-proposals will be evaluated by the program committee. The STW board will decide on the funding of the full proposals.

Program requirements

The main criteria for assessment whether a specific project application falls within this program are the following:

- The projects should focus on studying a bio-based concept that aims to solve an engineering challenge in at least one of the four Key Application Fields: production of materials, construction, maintenance, and reduction and recycling of waste;
- The project description should clearly state which essential research topics will be addressed and how the expected results strengthen the fundamental knowledge base for the chosen bio-based concept, but also how the fundamental knowledge would be valuable for the complete building cycle.
- The project should be carried out by at least two clearly collaborating researchers (PhD or Post-docs). This collaboration should at least be a combination of geo or civil engineering and biology. If necessary, researchers from other backgrounds can be added;
- The project is based on a collaboration between two academic groups. The proposal must make clear how the collaboration between the groups will be implemented and it must be apparent how the different knowledge fields and expertise domains are integrated;
- Projects must contain excellent scientific research with an innovative approach;

- The ultimate goal of this program is to achieve a significant reduction in the ecological foot-print of the geo and civil engineering sector. The proposal must provide a clear indication how the proposed process will lead to this reduction, what potential problems are expected and how the project aims to solve these problems.

Not eligible for this program

The program explicitly aims for concepts that integrate biological processes in the geo and civil engineering building cycle. The following topics are excluded from this program:

- concepts based on bio-mimicry, where biological solutions are copied using the biological processes;
- the well established fields of waste water treatment and remediation of soil contamination;

For further details of the time planning, proposal application and selection process please see the call for pre-proposals.

Program Committee

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- Prof.dr.ir. A.Q.C. van der Horst (co-program leader)
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- Prof.dr. R.N.J. Comans
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- Prof.dr. O. Adan
  TNO Bouw & Ondergrond / Faculty of Applied Physics, Eindhoven University of Technology
- Prof.dr. J.A. van Veen
  Netherlands Institute of Ecology (NIOO-KNAW) / Faculty of Science, Leiden University
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Appendix A. List of people invited and present at the workshop

Genodigden workshop BIOGEOCIVIL 10 december 2009

Bedrijf	Contactpersoon:	Aan wezig	Geo/ Civil	Bio
Akzo Nobel Energy B.V.	Hans Feenstra	ja		x
BAM Infraconsult bv	Ir. Jeanette Bouwmeester	ja	x	
CUR	Jan Mijnsbergen	ja	x	
Deltares	Hans Groot	ja	x	
ECN	Prof. dr. Rob Comans	ja	x	
EPT - Exploratory Research, Shell International Exploration and Production B.V.	Bart Lomans	ja	x	
Havenbedrijf Rotterdam	Wim Zwakhals	ja	x	
Koninklijke Vopak N.V.	Willem van der Zon	ja		x
Koninklijke Vopak N.V.	Bart van Holst	ja	x	
Min LNV	Cornelis Mijnders	ja	-	-
Ministerie van VROM	Margot de Cleen	ja	-	-
NIBE, Nederlands Instituut voor Bouwbiologie en Ecologie bv	Michiel Haas	ja	x	
NIOO-Yerseke	Lucas Stal	ja		x
Prominent	Marco van Noord	ja		x
Prominent	A. van der Lans	ja		x
SenterNovem	Corry van Driel	ja	-	-
STW	Corine Meuleman	ja	x	
Tauw BV	Dr.ir. Han de Wit	ja		x
TNO Bouw & Ondergrond	Prof. dr. Olaf Adan	ja	x	
TU Delft, BT/Environmental Biotechnology	Dr.ir. Gerard Muijzer	ja		x
TU Delft, Section Geo-engineering	Dr.ir. Timo Heimovaara	ja	x	
TU Delft, Section Geo-engineering	Dr.ir. Leon van Paassen	ja	x	
TU Delft, Section Materials & Environment	Prof.dr.ir. Klaas van Breugel	ja	x	
TU Delft, Section Materials & Environment	Dr. Ir. Henk Jonkers	ja		x
Unesco-IHE	Prof.dr.ir. Piet Lens	ja		x
Universiteit van Amsterdam, Instituut voor Biodiversiteit en Ecosysteem Dynamica	prof.dr. W. (Wim) Admiraal	ja		x
Volker Staal en Funderingen	Bartho Admiraal	ja	x	
Wageningen University	Dr. ir. Tim Grotenhuis	ja		x
AVEBE U.A.	Hylke Simonides	nee		
BAM Infraconsult bv	William van Niekerk	nee		
BAM Infraconsult bv	Prof. Dr. Ir. A.Q.C. Van der Horst	nee		
Bioclear BV	Sietze Keuning	nee		
Biosoil BV	Arnout van Diem	nee		
Boskalis	Wim Rosenbrand	nee		
Movares	Piet van Duijnen	nee		
NIOO-Heteren	Prof dr Johannes A (Hans) van Veen	nee		x
Prominent	Margreet van de Bos	nee		
ProRail	Arend Kremer	nee		
Rabobank, Westland	Richard van de Merwe	nee		
Royal Haskoning	Piet van Putten	nee		
RWS, Waterdienst	Pieter Janssen	nee		
SenterNovem	Harry Vermeer	nee		
Tauw BV	Ir Laurent Bakker	nee		
TU Delft, BT/Environmental Biotechnology	Prof. dr.ir. Mark van Loosdrecht	nee		
Utrecht University	Prof. dr. R.J. Schotting	nee		
Utrecht University	Prof. dr. ir. S.M. Hassanizadeh	nee		
Wageningen University	Prof. dr.ir. Huub Rijnaarts	nee		
Waternet	Karin Bosklopper	nee		