B économique

Return address:
SINTEF MEDIA
NO-7465 Trondheim
Norway

SPRING • 2009

RESEARCH NEWS FROM NTNU AND SINTEF

GEMINI

AN ENGLISH EDITION OF GEMINI IS PUBLISHED TWICE A YEAR. THE NEXT EDITION IS SCHEDULED FOR AUTUMN 2009.

Photo: FW/AS/NTNU Info

SINTEF and NTNU have projects related to CO_2-capture and management worth more than 100 million euro. This makes us one of the major international centres of R&D in this field.

NTNU's Kavli Institute is solving the brain's enigmas by mapping out the hardware of our memories.

SINTEF is in charge of EU's largest bioenergy research project with a budget of 29 mill. euro over a 4-year period. Seventeen partners from 7 countries are participating in this effort.

GEMINI
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Secrets of forgetting

Alzheimer's disease takes you into the darkness. A laser light and a detective molecule lead you out.

• 20

DRUGS FROM THE SEA

Scientists find new antibiotics

GOLDEN CARBON

More energy from the sun

THE 80 PER CENT SOLUTION

Recycling used water can help avoid a crisis

GEMINI

Spring 2009

GEMINI is published by SINTEF and NTNU in Trondheim, Norway. Gemini is published twice a year in English. Circulation: 8 000.

SINTEF

Editor SINTEF: Åse Dragland
Email: Ase.Dragland@sintef.no
Phone: +47 73 59 24 76
Reporters:
Svein Tønseth and Christina B. Winge
Editor-in-chief SINTEF:
Director of Communications
Petter Haugan
Postal address:
Gemini, SINTEF, NO-7465 Trondheim

SINTEF is the largest independent research institution in Scandinavia with 2 000 employees. We solve our customers' problems through research contracts in the following fields: Health, information and communications technology, marine activities, materials science and applied chemistry, petroleum and energy, technology management and building/construction. SINTEF intends in this way to act as a driving force in the process of restructuring and developing Norwegian society.

NTNU

Editor NTNU: Nina Tveter
Email: nina.tveter@ntnu.no
Phone: +47 73 59 53 21
Reporters:
Tore Oksholen, Lisa Olstad and Synnøve Ressem
Editor-in-chief NTNU:
Information Director Christian Fossen
Postal address:
Gemini, NTNU Info, NO-7491 Trondheim

NTNU – the Norwegian University of Science and Technology in Trondheim represents academic eminence in technology and the natural sciences as well as in other academic disciplines ranging from the social sciences, the arts, medicine, architecture to fine art. Cross-disciplinary cooperation results in innovative breakthroughs and creative solutions with far-reaching social and economic impact. NTNU has over 20 000 students and an academic staff of 2 500, of which one-third have permanent research appointments. The university awarded 3 300 degrees in 2007. One-third of these degrees were awarded to women. About 40 per cent of NTNU's degrees are in technology.

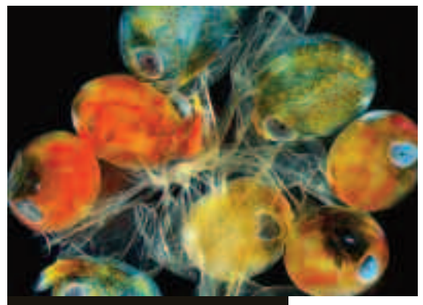
Internet: www.ntnu.no/gemini/english
Print: Aktietrykkeriet
Design/production: Tor Høyden and Raymond Nilsson, SINTEF Media
Mads Nordtvedt and Kolbjørn Skarpnes, NTNU Info
Cover photo: Digital Vision Singles
Translation and English editing: Hugh Allen, Stewart Clark and Nancy Bazilchuk.

Sick of the health system?

Norwegians who suffer from rare disorders feel that they are left to face their problems alone. **page 6**

Catching rays for supper

Preheat your oven might mean simply putting it out in the sun. **page 18**



Top imaging

These are lobster eggs, seen just before hatching. The eggs have a diameter of 2-3 millimetres. **page 12**

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Photo: Vince Michaels. Illustration: Raymond Nilsson

AN EYE FOR DETAIL

A new x-ray detector divides the radiation into different energy levels by counting the number of photons. This gives an image with more colours and numbers of combinations.

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FROM THE DIRECTORS´ CHAIRS

Unni Steinsmo, SINTEF's president – CEO
Torbjørn Digernes, NTNUs rector

Norway´s renewable energy investment

The Research Council of Norway has named eight national research centres for environmentally friendly technology. Each centre will receive up to NOK 20 million a year for five years.

The eight research centres will focus on topics ranging from wind, solar and bioenergy to CO_2 capture and storage and zero emission buildings. Research groups at SINTEF/NTNU are either running the centres or participating in six of them.

The development of technology in this field will be one of Norway's most important contributions to prevent or slow down climate change.

We believe that the new centres will be an extremely important facet of Norway's international efforts in the field of climate technology. The research centres in Trondheim are already collaborating extensively with industry and leading research groups in Europe, the USA, China and Japan on climate technology. Now, we will build on these contacts and develop both technology and an awareness of what is needed to produce an energy revolution.

> "Norway can contribute to making cuts in global emissions that will be several times as large as those we can make here at home"

Together with our partners, we will contribute actively to ensuring that both Norway and the global community will benefit as much as possible from our efforts. As a supplier of knowledge and technology on an international level, Norway can contribute to making cuts in global emissions that will be several times as large as those we can make here at home.

This goal is to be achieved by means of three main strategies:

– A major increase in electricity generation from renewable sources such as wind, solar power and biomass

– Capturing CO_2 emissions from fossil sources of energy such as coal, oil and gas

– More efficient end-use of energy.

Power from the forest

Photo: Morguefile

Even the planned increase in combined thermal energy and power schemes will be insufficient to meet the Norwegian government's goal of generating 14 TWh from bioenergy sources by 2020. Scientists believe that electricity will also have to be generated from our forests.

This is why SINTEF is working on a project that goes by the name of KRAV and which will map out how Norway can exploit its timber as a source of energy. Four Norwegian electricity companies, Trondheim Energi, Agder Energi, Eidsiva Energi and Solør Bio-energi, will participate in the project.

The aim is to identify the ideal technology for small-scale electricity generation from Norwegian forest products, while as much energy as possible is extracted from the biomass. As a first step, the scientists envisage systems with a capacity of up to 10 MW.

Can artistic expertise improve commercial value?

The Ministry of Industry and Commerce has financed a one-year research project in which SINTEF researchers have been studying whether collaboration with an artist can improve conditions within a company. Until now, sponsorship has been the most usual form of collaboration, rather than suggesting models for cooperation and added value. The project report offers twelve examples of successful collaboration.

Boen Parkett in Risør asked artists to design a unique and environmentally appropriate timber floor for its product range. A percussionist composed a work that includes the sounds of rubbish being emptied by Bergen's waste collection department, which uses the "music" in its self-profile. The photo shows a wall of material collected from a boatshed, which car mechanics in the Lie group of companies used to create a work of art.

Photo: SINTEF Technology and society

Ultrasound prepares parents

Photo: DHD Multimedia Gallery

Increasingly better ultrasound technology can show more foetal aberrations, often during a routine examination undertaken in the 18th week of pregnancy. These aberrations typically reflect chromosomal problems, syndromes, illnesses and de-formities. Nevertheless, this new information has not increased the number of pregnancies being terminated, according to an NTNU PhD research project conducted by Kristin Offerdal.

She studied nearly 50 000 pregnancies and found that women did not chose an abortion after deformities such as clubfoot or cleft palate were found, unless there were life threatening or fatal conditions. On the other hand, the information from the ultrasound helped prepare par-ents to care for their malformed or sick baby.

Diving to the bottom of climate change

Climate change and rising sea levels will give diving a new and larger role than in the past. We have to assume that we will increase our use of the sea for food production, and that we will have to turn to the sea for energy from oil and gas, wind and waves. All these things will require divers, and consequently research on diving. "We have to im-prove the technology and find out more about how the underwater environment affects people," says NTNU's foremost expert in diving physiology, Professor Alf O. Brubakk.

Early signs of allergy

Children who react to both pollen and fruit during their first two years of life are at serious risk of developing allergies. This has been demonstrated in studies carried out by Xiao-Mei Mai of SINTEF Health Research and scientists at the Karolinska Institute in Stockholm. Of the 3619 one- to two-year-olds that they studied, 228 (6.3%) displayed a reaction to pollen while 215 (5.9%) produced reaction symptoms to fruit, including nuts. Fifty of the children (1.4%) had a reaction to both ingredients. This little group was at considerably greater risk of developing a number of allergic diseases such as asthma and eczema when they were studied again as four-year-olds. The children who had only displayed reactions to either pollen or fruit, on the other hand, were at no greater risk than other children.

Photo: Morguefile

Photo: Terje Thun

Norway's oldest stave church

The ground under the Urnes stave church is sinking, and this national treasure in Sognefjord has begun to sink at its northern end. Research-ers from NTNU worked in the summer of 2008 to determine how the church can be lifted and sta-bilized without being ruined. At the same time, dendrochronologist Terje Thun took tree ring samples from the oldest wood. The samples confirm that the church was erected over a longer period in the 1130s.

At the same time it was shown that a portion of the church – including the north wall, with its spectacular carvings – was actually recycled material from another church that previously stood at the same spot. The youngest of these timbers were felled around 1070. This is the oldest Norwegian church building material that has been dated.

Sick of the health system?

Norwegians who suffer from rare disorders feel that they are left to face their problems alone.

RARE DISEASES **SUPPORT SYSTEMS**

CONTACT: Lisbet Grut, SINTEF Health Research
PHONE: +47 993 68 151
EMAIL: lisbeth.grut@sintef.no

Photo: Resource Centre for Rare Disorders

RARE DISORDERS: This girl suffers from the diagnose "Retts Syndrome" which is a severe disturbance in the development of the brain. The picture is from a "sensory path" where children's vision and senses are stimulated.

Some 30 000 people in Norway suffer from rare hereditary or congenital disorders. They can be further divided into several groups, in which fewer than 500 share the same diagnosis.

Senior research scientist Lisbet Grut of SINTEF Health Research has led an in-depth study of such people. In a project carried out on behalf of the Directorate of Health, Grut interviewed 94 people from eight diagnostic groups and from the national centres for rare disorders that they attended.

A FEELING OF FALLING OUTSIDE THE SYSTEM • "People who have been diagnosed with rare disorders often encounter mistrust and a lack of sympathy in their meetings with the support system. Since they themselves know a good deal about the treatment, measures to be taken, risks and consequences of their diagnoses, they expect to be listened to and respected. But when they meet health service personnel, they find it difficult to get through to them," she says.

All of the subjects in the study had experienced that health service personnel outside the national centres did not know about their rare disorder diagnoses. Many of them did not place high priority on acquiring such knowledge either, but made their decisions on the basis of what they assumed to be correct. When local follow-up took place, it was usually dependent on individual health personnel becoming interested in a particular case.

"Patients who have been diagnosed as having a rare disorder share a perception of having fallen out with the conceptual universes of the experts," says Grut.

DIAGNOSIS TAKES TIME • What these rare disorders have in common is that they are incurable. Nevertheless, many people can benefit from ameliorative treatments and various types of adaptation.

The group studied by Grut includes people suffering from cystic fibrosis (a multi-organ illness that attacks the respiratory and digestive systems), Usher Syndrome (double loss of hearing and vision) and bladder exstrophy (malformation of the bladder, urinary tract or sexual organs).

DISORDERS: But treatments and adaption help.

Several of the participants in the study say that it took a long time for a diagnosis to be made. In many cases, not even their closest relatives understand what is wrong with them.

SPECIALITY CENTRES • Because personnel in the general health service system seldom or never come into contact with rare disorders, a network of national centres has been set up for each disorder. These centres are intended to offer support to the people who have been diagnosed, their families, and professionals at all levels. However, about half of all people who have been diagnosed as having a rare disorder still lack such a national centre that they can attend.

HUMBLE BEHAVIOUR • Almost all the interviewees had dealings with NAV (the Labour and Welfare Administration), and many of them felt that their cases were dealt with in a rigid manner and that their actual needs were not taken sufficiently into account.

Many of the respondents found that in order to obtain help they had to emphasize the most negative aspects of their condition. Many of them said that they realize that they need to behave in a "polite, humble and obsequious" fashion, and they try to develop strategies for communicating with their case officer.

By Åse Dragland

Drugs from the sea

For the first time, Norwegian scientists have managed to produce completely new antibiotics from bacteria found in the sea.

MEDICINES **BIOPROSPECTING • BACTERIA**

CONTACT: Håvard Sletta, SINTEF Materials and Chemistry
PHONE: +47 930 86 028
EMAIL: havard.sletta@sintef.no

Eleven species of bacteria that create substances that kill cancerous cells and three other bacteria that produce new antibiotics were discovered by scientists at NTNU and SINTEF.

In collaboration with research groups in Moscow and the University of Bergen, they have made breakthroughs in the field of biotechnology. Never before have Norwegian scientists carried out the entire process from gathering bacteria from the fjords to presenting completely new interesting substances in bottles.

Behind their success lies a long and painstaking process of screening, cultivation, isolation and testing. However, it will still take some time before they can be sure that the process will continue to the phases of commercialization and medicine production.

A NETWORK IS BUILT UP • The NTNU and SINTEF researchers have been bioprospecting for five or six years, searching for interesting substances that are produced by marine bacteria. The wide range of expertise in this research group makes it unique, as it brings together competence in physiology and genetics, and has access to modern screening and fermentation laboratories.

The pace of the process has risen during the past few months, since the recruitment of Professor Stein Ove Døskeland's group at the University of Bergen, one of the best groups around in this field. The scientists have also had bacterial fractions tested in Russia.

NINETY PER CENT ARE OF NO INTEREST • Many of the bacteria that have been brought up from the Trondheim Fjord have antibiotic functions, but most of these are already known, and are therefore of no interest. New compounds that can be patented are more interesting.

"Substances with a new chemical structure and, we hope, with a different mechanism of action than we already know of, could be extremely valuable, for example in fighting cancer. This is why we need more candidate structures. Not all of them can be developed into new medicines, but if we are successful with one or two of them, we will be quite happy," says NTNU professor Sergey Zotchev.

Recent focus on a few selected bacteria has led to these exciting findings. In Bergen and Moscow, the 11 anti-cancer substances have been tested against leukemias and stomach, colon and prostate cancers.

"We have found that cancerous cells have been killed, while normal cells survive, and that individual extracts act on different types of cancer cells," says senior scientist Håvard Sletta of SINTEF. "However, we still have not identified the active substances in the compounds produced by the bacteria".

MUCH WORK STILL TO BE DONE • Meticulous laboratory experiments have enabled the scientists to identify the chemical structure of one of the three substances that can be used as antibiotics, and which they now know act against multiresistant bacteria. During spring, this substance is due to be tested on animals in Moscow. If the results turn out to be positive, the way will be clear for a patent application.

"If it turns out that this substance does not work in animals, the worst that can happen is that there will be a pause in our efforts. However, in many cases, all that is needed to take us further is a chemical modification of the molecule, but that requires a lot of work, and we could be stopped by lack on funding," says Zotchev.

"We need to remember that bacteria from the sea produce antibiotics in order to deal with their own natural competitors, rather than to act against infections in the human body."

By Åse Dragland

Photo: Thor Nielsen

DEMANDING: Senior scientist Håvard Sletta of SINTEF and Professor Sergey Zotchev of NTNU have been collaborating on identifying valuable types of bacteria..

A longer life with a Superman bicycle

A new type of exercise equipment can prevent serious lifestyle illnesses in paraplegic patients. The equipment, which was partly developed at NTNU, was first designed for the American actor Christopher Reeve.

MEDICINE **PHYSIOTHERAPY** • **TRAINING**

CONTACT: Jan Hoff, Department of Circulation and Medical Imaging, NTNU
PHONE: +47 73 59 17 79 **EMAIL:** jan.hoff@ntnu.no

Photo: Vegard Eggen

READY FOR INTERVAL TRAINING: Terje Roel is paralysed as a result of a spinal injury. Here Berit Brurok is readying him for a demonstration of the arm and leg cycle.

Patients who are unable to walk after a spinal injury have a poorer quality of life and a shortened lifespan than their non-paralysed counterparts. Sitting passively in a chair makes people susceptible to weight and digestion problems, lower bone density, diabetes – and last but not least, heart and circulation problems.

"It's the circulation problems that are the most difficult for them, and it's circulation problems that kill them," says Jan Hoff, a professor of medicine at NTNU.

But it does not have to be that way. A new type of exercise equipment, partly developed at NTNU, combined with a new training plan, makes it possible for spinal patients to exercise and enjoy improved health – at least as far as the heart is concerned.

In an exercise study completed last year, patients who were paralysed from the chest or waist down experienced an average increase in their maximal oxygen uptake by 25 per cent and in their heart pumping volume by fully 37 per cent – after just eight weeks of training.

Never before has so much improvement or such impressive results been documented in this patient group.

NOT JUST A STATIONARY BIKE • This clever training equipment is called *Ergys 2*, and was originally designed in the United States. It was Christopher Reeve – who himself played Superman in films, but who became a quadriplegic after a riding accident – who financed the development of the rehab equipment, in the hopes of improving his own health. But that did not happen as the actor died of heart failure when he was just 52. Nevertheless, his efforts gave the world's spinal injury patients a useful piece of rehabilitation equipment.

The Ergys 2 is a stationary training bicycle, where the patient's legs and feet are strapped to a leg holder and pedals. Electrodes are then fastened to the patient's thigh and seat muscles, and electrical impulses trigger the muscles to contract and relax. The impulses are computer controlled to guarantee the best possible effect.

Even though it may seem like artificial training, it is real enough – it is the patient's own muscles that are working. And it is movement that demands energy: the blood flow increases, and the pulse goes up. The exercise has an effect on muscle mass, muscle strength, oxygen uptake and the heart's pumping volume.

HARD WORKOUTS, FEW REPETITIONS • But it is not enough to focus on the legs and buttocks, if this kind of training is going to make a real difference. The more muscle groups that are involved, the greater the blood flow, and the more beneficial it is for the heart. That is where the NTNU researchers come into the picture. They have found a way to supplement the Ergsys 2 with an arm cycle, intended for patients who can use their arms without help.

The patients who participated in the training study were also able to simultaneously exercise their shoulders, arms, buttocks and legs, in a high intensity interval 4 x 4 minute pattern. That translates into four minutes of hard exercise followed by three to four minutes of easier training – with the entire procedure repeated four times per session, three days a week.

NTNU's Professor Jan Hoff developed this interval approach several years ago, along with his colleague Jan Helgerud. He uses this interval technique for most types of physical training.

"Hard workouts, few repetitions. There is no other training approach that gives better results in improving oxygen uptake or muscle strength than that," he says.

A PREVENTATIVE APPROACH • Never before has research documented such a significant effect on the heart and circulation in patients with spinal injuries, as the study has shown. There has been relatively little research overall on spinal patients and exercise, in terms of what kind and how much exercise actually gives beneficial results.

The patients in this study were so out of shape when they started that they were unlikely to reach a normal level. But Hoff does not think this is an impossible goal.

"We really don't know, but there's no reason to believe that the improvements will stop where they are now," he says.

Hoff does not want to speculate on the implications of his research on the treatment of Norwegian patients paralysed from spinal injuries.

"We are researchers, not therapists," he says. "But it is clear that what we are doing has consequences, both for Norway and for the world. And that gives us a great opportunity to prevent lifestyle-related illnesses."

UNPLUGGED? • Under Hoff's guidance, Berit Brurok conducted the study for her master's thesis in exercise physiology. Berit Brurok is continuing her work in this area as a part of her PhD research, in cooperation with Dr Tom Tørhaug at St. Olavs Hospital in Trondheim.

Because the Ergys 2 is expensive, and because it also requires assistance to use it, the researchers are looking to see if the results from the study can be transferred to other activities. Would it be possible to do something similar in a wheelchair? Could it be done without electricity?

If they succeed, it could mean a better quality of life and a longer life for many people. In Norway alone there are 5000 spinal injury patients, while in the USA that number may be closer to 500 000.

By Lisa Olstad

Threatened language

Only several hundred people currently speak Southern Sámi. But the language refuses to die.

LANGUAGE **SOCIOLINGUISTICS** • **SOUTHERN SAMI**

CONTACT: Inger Johansen, Department of Scandinavian Studies and Comparative Literature, NTNU
PHONE: +47 73 59 67 98 **EMAIL:** inger.johansen@hf.ntnu.no

There are roughly 1000 southern Sámis living in Norway, and perhaps the same number in Sweden. They are widely spread and many make their living from traditional reindeer husbandry and live a half-nomadic life. Their main language for many years has been Norwegian or Swedish, and no one really knows how many now speak Southern Sámi. Estimates put the number of speakers somewhere around 500.

A language this small has the odds against it. Several Sámi languages have already died out, and Southern Sámi is high on the United Nations "red list" of endangered languages.

But against all odds, the Southern Sámi language is rising from its deathbed.

THE TABOOS ARE FALLING • "I am an optimist," says Inger Johansen, a PhD candidate who works at NTNU. She is researching the Southern Sámi language community, including how Southern Sámi is being revitalized. That is exactly what researchers are witnessing: a revitalization of the language. This is occurring on several levels, including an official level.

Last year, the mid-Norwegian municipality of Snåsa was bilingual. Southern Sámi was used for the first time as an administrative language along with Norwegian. That meant that all public services and information must be offered in both languages. The commitment also obligates the municipality to protect, strengthen and advance the use of Southern Sámi.

Snåsa is one of the places where Southern Sámi is strongest – even though only about 5 per cent of the population uses it. The community is also home to a Southern Sámi cultural centre, a Southern Sámi boarding school and a kindergarten.

"But right up until very recently you would scarcely hear Sámi spoken on the streets in Snåsa," Johansen says. "It was kind of taboo. But the taboo has fallen, and more and more Southern Sámi speakers speak Southern Sámi when they meet."

A SENSE OF PRIDE • Not everyone wants to call attention to their Sámi background, however, even though the active stigmatization and victimization of Sámis more or less ended in the 1960s.

But steadily more are taking back their Sámi identity.

"A whole new generation is growing up now with a completely different relationship to language, pride and identity. Many who didn't learn Southern Sámi as a mother tongue when they were children have now decided to use it as their home language, and make certain that it is passed on to their children," Johansen says.

She also believes that the unbelievably strong ties among Sámis, and their willingness to often travel long distances to meet friends and family is important in maintaining Sámi identity and the language.

By Lisa Olstad

Photo: Leif Arne Holme

FUTURE SÁMI SPEAKERS: This Southern Sámi kindergarten hopes that the children there will be able to use Southern Sámi in their daily lives.

Safer with light metals

Photo: Ahmad Masood/Reuters/Scanpix

COMPLEX PROBLEM: When a landmine explodes, an unprotected vehicle will be thrown into the air by sand and air pressure. In the future it is possible that plates of aluminium foam will absorb the pressure.

A cheap and simple structure made of aluminium can mean the difference between life and death the day that bombs go off.

MATERIAL SCIENCE **PROTECTIVE STRUCTURES**

CONTACT: Professor Magnus Langseth,
Department of Structural Engineering, NTNU
PHONE: +47 73 59 47 82
EMAIL: magnus.langseth@ntnu.no

A soldier in war lives a life exposed to danger both inside the compound fence and on assignment outside the base. If the container barracks are struck by a direct hit, they can be transformed into a clump of twisted metal in a matter of seconds. If a soldier drives over a landmine, the vehicle and those inside can be blown sky high.

War is never safe. Nevertheless, it is possible to protect soldiers from at least some of the dangers. Armoured steel and concrete provide good protection, but structures made from steel or concrete are very heavy, and can be difficult to move. Aluminium, on the other hand, is a lightweight product, in a number of different ways.

SIMLab (the Structural Impact Laboratory) is one of the Norwegian University of Science and Technology's three Centres for Research-based Innovation. One of SIMLab's research projects is developing aluminium structures for protection against impacts, projectiles and explosions.

"We have developed a light, cheap and flexible solution to protect buildings, ammunition magazines and containers", says the head of the centre, Professor Magnus Langseth.

WITHSTANDS MOST • The solution has grown out of the close cooperation between the Norwegian Defence Estates Agency (NDEA) and NTNU. NDEA is responsible for the Norwegian camps and compounds that are involved in international operations, and has financed the centre's research on protective structures for both military and civilian use for a number of years.

The panel in question is made from an aluminium profile with holes filled with a heavy substance found on site, such as sand, gravel or small stones. These aluminium profiles are easy to produce by extruding them through a shaped die that gives them the desired cross-section. They are also easy to move and are assembled using a click system to form a panel. Each profile is placed in a lifting device and is mounted on a container wall, for example. Afterwards it can be filled from the top with gravel, which then can be emptied from the bottom when the panel needs to be moved to another area.

Two men can erect a container building in this manner in the course of a morning.

"These filled aluminium shapes can withstand projectiles and explosives," explains Tore Børvik, who works with NDEA and is an adjunct professor at NTNU working at SIMLab.

SURVIVED THE TEST • The aluminium panel system has been tested at full scale with a blast from an explosion. It demonstrated its effectiveness: the panelled container sustained minor damage from the blast, which was equivalent to 4 tonnes of TNT detonated at a distance of 120 metres. Without the lightweight metal protection, the container would have undergone serious damage. But a few details remain to be improved, so the system is not on the market yet. Nevertheless, a number of NATO countries have already shown interest in it.

"NTNU is not in the business of producing these things," Professor Langseth says. "Our job is to develop the tools that product developers need. We make computer models, and experiment with alloys and design. The tools for this type of protection need just a bit more work before they're ready."

ON DANGEROUS ROADS • Only a few of the vehicles used by peacekeeping forces are protected from landmines. Armoured steel is expensive, but first and foremost it is heavy – and many places are inaccessible to a vehicle armoured with steel. A vehicle needs lightweight protection.

Aluminium is just such a material. But a gravel-filled panel is too heavy, and is not suited to be mounted on a vehicle chassis. So SIMLab's researchers are working to develop lightweight plates made from aluminium foam that in time may be the solution to the problem.

"This is an extremely complex challenge," Professor Langseth emphasizes. "When a landmine explodes, the combination of sand and air pressure tosses the vehicle and the driver up in the air. We have to find a method to absorb the pressure, something that is lightweight and doesn't take much space. We haven't yet developed the technology, but we're working with the design tools that we have already developed."

SIMLab has now been invited to join an international research project with some of the world's leading researchers in mechanics and materials, where the theme is protection of vehicles in war zones.

By Lisa Olstad

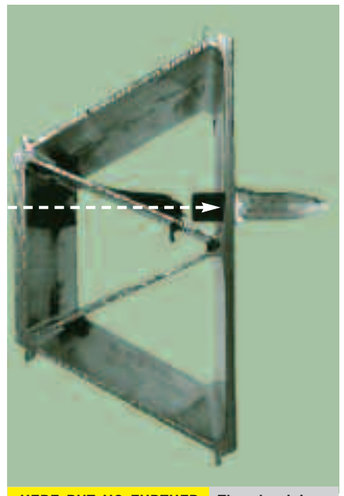


Photo: SIMLab

HERE BUT NO FURTHER: The aluminium profile seen from above. A projectile has penetrated the outer wall from the left and has passed through two layers of aluminium, but was stopped by the third – even though it was not filled with sand or gravel.

Moving underground

Photo: Google Maps

DIGGING IN: The city of Singapore is crowded and has reached the limits of expansion.

Scientists from Trondheim are helping Singapore to move its infrastructure underground.

BUILDING TECHNOLOGY **TUNNELS • INFRASTRUCTURE**

CONTACT: Ming Lu, SINTEF Building Research
PHONE: +47 73 59 68 77
EMAIL: ming.lu@sintef.no

In spite of its small size, Singapore has a population of five million, and it is an important communications node for both sea and air.

This is why the authorities are now considering moving some of city's infrastructure underground. Every area must be carefully evaluated before any decision is taken, and this is what the Singaporean authorities want Norwegian tunnel experts to do.

STRONG REPUTATION ABROAD • The fact is that Norwegian expertise in building and using underground facilities is in high repute in other countries – not least where exploiting the construction characteristics of the rock mass is concerned. Since the Second World War, Norwegian tunnel engineers have gained substantial experience in building tunnels and caverns for many different purposes, including storage rock caverns for oil and gas, hydropower projects and swimming pools and sports areas.

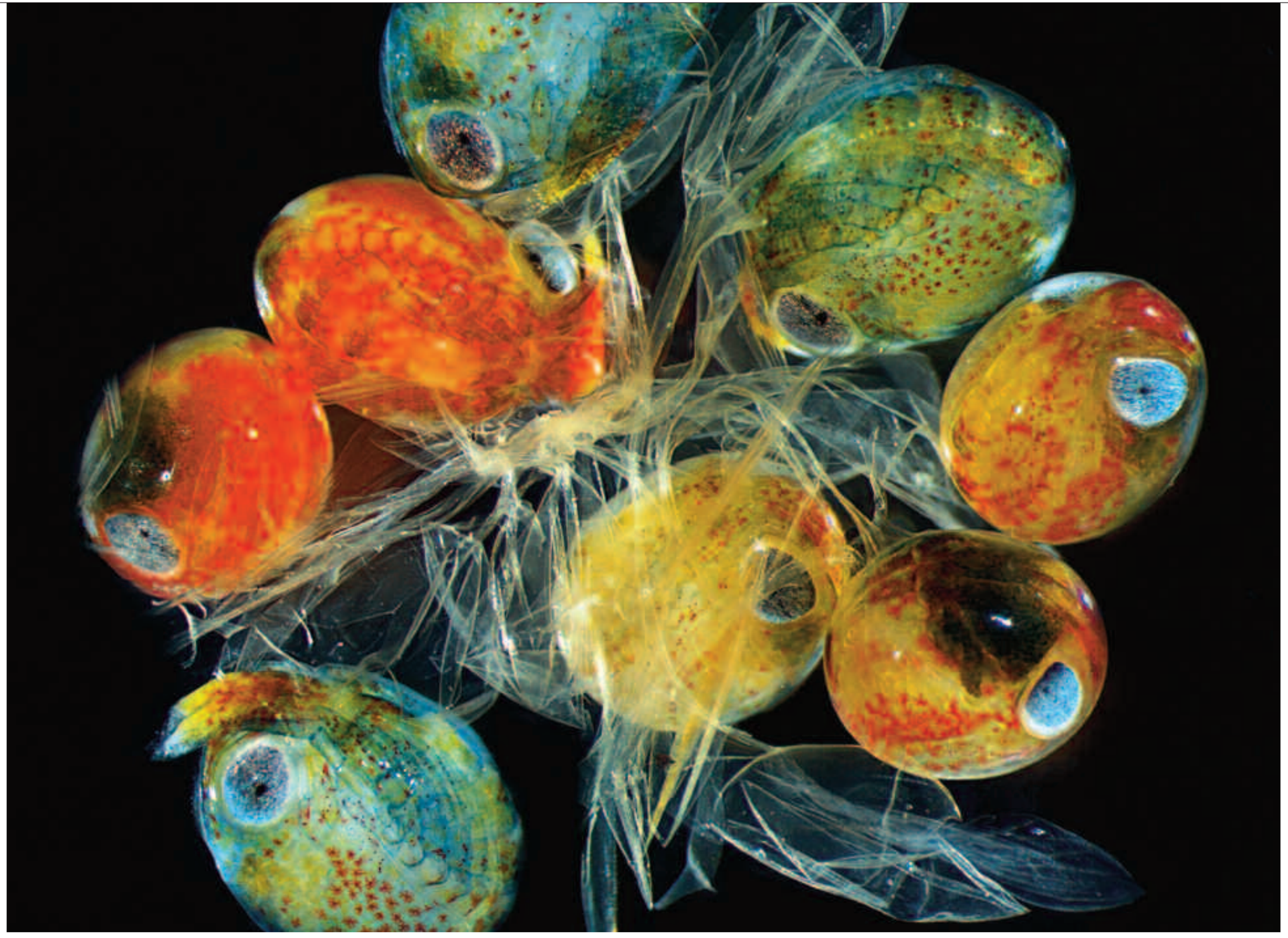
Today, SINTEF Building Research is in the process of developing subsea tunnel projects in Iceland, the Åland Islands and the Faeroes. The scientists are acting as consultants in the construction of a 25 km-long sewage tunnel under Hong Kong, and are also involved in other projects in China and India.

BASIS FOR DECISION-MAKING • SINTEF is operating in a consortium together with Multiconsult and a local company, TriTech. "We set up this joint effort some years ago, and it has turned out to be a useful bridgehead into Singapore," says Grøv.

The Trondheim scientists, who were awarded the contract in 2008, have been using the time since then to collect examples of similar projects that have already been performed in such fields. In the course of the next nine months, and on the basis of three examples from each field, they are to develop appropriate solutions for Singapore. The ministries involved will use these as a basis for decision-making.

LARGE DIMENSIONS • "We are talking about large areas all over the island," says chief scientist Ming Lu of SINTEF Building Research, who has led the earlier Norwegian efforts in Singapore. "If these facilities are built, the process will involve digging shafts, boring access tunnels and building huge caverns. It is extremely interesting for us to contribute to a job like this, since we are talking here about the first project of such dimensions anywhere in the world".

By Åse Dragland



Top imaging

These are lobster eggs, seen just before hatching. The eggs have a diameter of 2-3 millimetres. The image was taken through a microscope while Tora Bardal at NTNU's Department of Biology and Johan Evjemo at SINTEF Fisheries and Aquaculture measured the diameter of the eggs to find out how long it would be until they hatched.

Their work is part of a larger effort to transform Norwegian lobsters into a productive aquaculture species. The image was selected by *Scientific American* as one of the 10 best in the magazine's 2008 Olympus Bioscape Digital Imaging Competition.

Photo: Tora Bardal

GOLDEN CARBON

Photo: Geir Mogen © SINTEF Media

This powder has the colour of our cold northern nights. But it is hot news for everyone who wants to extract more electricity from sunshine.

MATERIALS SILICON • SOLAR CELLS • CARBON

BY: Svein Tønseth
CONTACT: Aud Wærnes, SINTEF Materials and Chemistry
PHONE: +47 930 59 428 **EMAIL:** Aud.N.Warnes@sintef.no

An outstretched hand gives me a firm welcome. Then it pulls on a big blue glove and dives into a brown paper bag. A second later, chief scientist Aud Wærnes has a fistful of stuff that could be icing sugar – if only it hadn't been pitch black.

"Did you know that car tyres were white until the world got powder like this?", says the quiet Norwegian voice, then she continues:

"This stuff is dirty and messy. But if everything goes according to plan, it will soon be in use as an ingredient in a process that will help to make tonnes of a metal which will be pure enough to be turned into solar cells."

Her voice is eager. For ten years, Aud Wærnes and her colleagues have been involved in a race to give the world more solar cell-quality silicon, a scarce material. Now they can see their goal approaching.

In her glove, the SINTEF scientist is holding billions of carbon particles, known in the trade as Carbon Black. Most industrial-quality Carbon Black still ends up in car tyres, but the version that is being produced by SINTEF and its partners is far purer.

ULTRAPURE CARBON • Carbon is what silicon smelting furnaces need to be fed with in order to convert quartz to metallic silicon, which is the principal component of most solar cells. Starting with ultrapure carbon, SINTEF, the Norwegian metal manufacturer Fesil and a handful of international partners have developed a new process for producing solar cell quality silicon.

The results were so promising that this autumn, Fesil's subsidiary Fesil Sunergy decided to base industrial pilot production of solar-cell metal on the process. Aud Wærnes makes it quite clear that we are talking about silicon produced at much lower cost and with lower energy consumption than the traditional raw material for these cells, but will it still give us efficient solar cells?

If all goes well, the first factory, to be built at a cost of more than a billion kroner, will be completed by 2011 and will provide between 100 and 150 jobs. The tug-of-war over where it is to be sited is already under way.

YACHT RACE WAS STEP-FATHER • In the autumn of 1997, two men met on a quay in Cape Town. That is where it all started; the story that has turned Aud Wærnes and her colleagues into solar cell pioneers.

The Whitbread Round the World Race circus had just arrived in South Africa. Thirty days after the start in Southampton, "Innovation", the Norwegian entry, moored to the quayside in Cape Town. The boat was skippered by Knut Frostad and was sponsored by Kværner.

The Norwegian industrial company had a development project that was being run by Aud Wærnes and her colleagues. The partnership had resulted in a new process for splitting natural gas into hydrogen – much in demand – and ever-increasing quantities of Carbon Black.

Adding Carbon Black to tyres makes them strong and resilient. The standard product used in tyres is produced from heavy oil from refineries. Natural gas, which is the raw material used by SINTEF and Kværner, is much purer, leaving the project partners with a type of carbon that contains far less foreign matter than ordinary Carbon Black.

As the yachts arrived in South Africa, two men were meeting and wondering whether the ultrapure black powder could find a new →

Aud Wærnes led SINTEF's and Fesil's solar cell project since its predecessor started in 1988 until 2005. Today, she is in charge of all of SINTEF's metallurgical activities. Her colleague Caspar van der Eijk is now project manager.

Photo: Geir Mogen © SINTEF Media

> "Did you mention "downturn"? We had lots of difficulties from 2002 until 2004."
>
> Aud Wærnes, Research Director

→ application beyond the walls of tyre factories.

One of these men was Kværner's "hydrogen and Carbon Black boss", the late Steinar Lynum. The other was Benno Wiersma, a Dutch businessman who was extremely enthusiastic about both sailing and renewable energy.

Lynum was keen to find alternative uses for Carbon Black, while Wiersma wanted to make money from solar cells.

TRIGGERED BY LONG-DISTANCE CALL • While the two men were chatting near the southernmost point of Africa, the solar cell industry was satisfying its still relatively modest hunger for silicon by consuming the leftovers from the electronics industry's plate.

Most solar cells employ a thin wafer of silicon, one of the most common materials on the earth's surface, as their active core. Silicon is the main component of quartz, in which it is combined with oxygen.

The two elements are separated at a temperature of 1800 degrees Celsius by the ferroalloy industry, from whose furnaces emerges melted silicon, known as metallurgical silicon, which is mostly used as an additive in aluminium alloys and to produce pure silicon, an ingredient in everything from jointing paste to cosmetics and babies' dummies. This material cannot be used direct from the furnace to generate solar power, as it first needs to be purified of other elements, traditionally an expensive and energy-intensive process.

Throughout its infancy, the solar cell industry has obtained its pure silicon by purchasing surplus material from producers of raw materials for the highly demanding electronics industry. Solar cells are made from manufacturing rejects and cutoffs from the ingots of ultra-pure silicon that are used to make the chips for PCs and other electronic devices.

BennoWiersma was aware of the solar cell industry's anxiety that sooner or later there would be a shortage of these traditional materials – metal that is purer than the solar cell industry really needs, since solar cells do not require silicon as pure as PC chips do.

Wiersma and Lynum also knew that ferroalloy plants use coal and coke in their furnaces to bind the oxygen in the quartz and thus separate it from the silicon.

While Africa's sun was shining over the Cape, the two men asked themselves if the ultrapure carbon from SINTEF could be substituted for coal and coke and become the key to a new type of smelter that would serve the solar cell industry. In other words, could this material, because it contaminates the metal less than coal or coke, produce silicon straight from the furnace that would be pure enough to be used in solar cells?

The men agreed to ring Trondheim and ask SINTEF.

HOTTER THAN DANTE'S HELL • Eleven years on, the calendar says 2008.

"We accepted the challenge right away," Aud Wærnes remembers, adding:

"Several years of research had already given us wide-ranging competence in producing metallurgical silicon. We had also worked on solar cell-quality silicon back in the 80s. For us, it was really exciting to be able to examine this topic at close hand."

She has just shown me into a high-ceilinged laboratory that looks like a workshop. We are surrounded by grey concrete walls in the heart of the Gløshaugen university campus in Trondheim. On a gallery above us towers a steel-clad monster, a presence that Wærnes and her colleagues are very fond of.

On the outside, the machine seems to consist of black pipework and heavy nuts and bolts, but Wærnes is more interested in its inner workings, for this is where the process that gives us pure carbon was born.

This process is based on plasma technology, and the productive "womb" on the gallery is a pilot-scale metallurgical plasma reactor, I am informed. A plasma is a gas whose atoms or molecules have been ionized (i.e. have become electrically charged). If an electric current is passed through such a gas, it can reach extremely high temperatures.

Standing under this machine, I listen to the history of the solar cell project that has been under way at Gløshaugen virtually since Aud Wærnes finished her telephone conversation on that memorable day in 1997; a story with its ups and downs.

PURE CARBON AND PURE QUARTZ • The phone call from Africa led to a pilot project that She started with her colleague Ola Raaness. This was followed by an EU project, in which SINTEF was joined by one of Wiersma's Dutch companies, plus the Swedish industrial company ScanArc and energy researchers from the Netherlands.

At Gløshaugen, Roar Jensen, Steinar Prytz, Ingeborg Solheim and Eivind Øvrelid were soon brought in, and all became long-term members of the project team.

The process being developed by the team has been christened "Solsilc", a name that must not be confused with "Sunsilk"! Clean hair has no connection with this matter, although other pure materials do play a role. The Solsilc process uses not only pure carbon but also extremely pure quartz. Metal recovery takes place in a specially modified furnace, from which the metal is fed into another furnace in order to remove any carbon that is still dissolved in the silicon.

"Benno Wiersma's vision was that we should contribute to the whole value chain, from metal production to creating acceptance for solar cells in society. It is not often that contract researchers like ourselves are handed such an opportunity," says Aud Wærnes.

But she also remembers times when funds were tight and the project was put on the back burner.

"Did you mention "downturn"? We had lots of difficulties from 2002 until 2004."

But it was in 2004 that the lack of traditional solar cell materials began to make itself felt, just as the growing solar cell industry had feared. Raw materials from the IT industry, which is not growing particularly rapidly, have become scarce. This adds weight to SINTEF's argument that the new process will make it possible to produce solar cell material in large volumes.

At that time, the EU team was producing silicon in small pilot-scale batches, while carbon removal was taking place at a large laboratory scale. SINTEF invited Fesil into the project as an industrial partner, and the company accepted.

"An important turning point," Wærnes points out as she looks back.

NEW FIRE IN OLD HALLS • This brought in a player with 30 years of experience of producing metallurgical silicon.

"We very extremely pleased about this, as it gave us an industrial company that possessed a great deal of experience which could be transferred to the new process", continues Wærnes.

After two years of cooperation with SINTEF and the other team members, Fesil and its Dutch project partners established the company Fesil Sunergy, with Fesil as its largest shareholder. In September 2008, the world was told that the company had got far enough to initiate full-scale test production of solar cell material, which will actually start during 2009.

The following day, I drive to a huge corn-coloured factory building on the outskirts of Trondheim. The gate is closed, with not a puff of smoke to be seen from its six rusty chimneys. This is Lilleby Smelteverk, established in 1927 and once famous for producing the purest ferrosilicon in the world, until it closed in 2002. Now the plant can draw a final, but vital, breath before it is demolished. This is where test production will take place. After the promising small-scale production phase in Sweden, Fesil Sunergy invested NOK 150 million (USD 21.5 million) in what is to take place in the hall in front of me.

Further to the east of the city, in an office building on the motorway to Værnes Airport, technical director Lars Nygaard in Fesil Sunergy shares office space with the rest of Fesil's management team. Nygaard explains that full-scale test production is important, not least for the sake of deciding on the right production equipment.

Nygaard makes no secret of the fact that the project has its risks, as do all technological developments. But he also points out that the NOK 150 million (USD 21,5 million) investment is an indication of the strength of the company's faith that the project will reach its goals. He tells me that any decision to build a new plant will be made in the second quarter of 2009 at the earliest.

"If we decide to build in Norway, it will probably be in Orkanger, but there are better possibilities of obtaining investment subsidies elsewhere in Europe, and that is tempting for the shareholders," he says.

On the way back to town I stop at Gløshaugen, where Aud Wærnes has removed her dirty gloves and is sitting in her office. Since she took that decisive telephone call from South Africa eleven years ago, the Round the World Race has changed sponsor, name and route, and there are no Norwegian yachts in this year's circumnavigation.

"All the same, we can always hope that life will offer an equally exciting phone call again," smiles Aud Wærnes, ready for the next stage of this race for the sun. ■

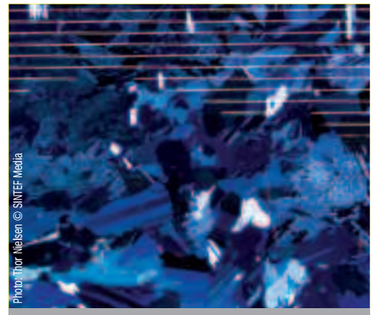


Photo: Thor Nielsen © SINTEF Media

NEW PRODUCTION OF SOLAR-GRADE SILICON

The lack of super-pure silicon has been holding back the growth of the solar energy sector. Norwegian companies are world leaders in the development of new, inexpensive methods of production of solar-grade silicon.

REC Silicon is building two new plants in the USA. These purify silicon in the gaseous phase and deposit the purified gas on silicon granules suspended in a fluidized bed reactor.

Elkem is about to open a brand-new plant outside Kristiansand; production will be based on a metallurgical process for purifying silicon.

Fesil Sunergy will start pilot production in 2009, based on a metallurgical process for the production of solar-grade silicon.

Hydro and Umicore are constructing pilot-scale equipment for the production of silicon for solar cells on the island of Herøya.

CATCHING RAYS FOR SUPPER

ENERGY **SOLAR HEATING • PROCESS ENGINEERING**

BY: Hege J. Tunstad
CONTACT: Habtamu Bayera, Department of Energy and Process Engineering, NTNU
PHONE: +47 73 59 38 90 **EMAIL:** habtamu.b.madessa@ntnu.no

Can our society move beyond the use of coal, oil and gas? The answer from researchers at the Norwegian University of Science and Technology is a resounding yes.

Habtamu Bayera Madessa came from Ethiopia to Norway to develop solar-powered technology for his homeland. His goal is to construct a simple, cheap and safe oven that both collects and stores heat from the sun.

PARABOLIC DISH CAPTURES SUN • There is not much natural sunlight shining through the windows of a cold Trondheim workshop on a January morning. We have come to see the prototype for a solar oven. But the sun has taken its winter holiday, and is of no help.

Habtamu is not alarmed by that and turns on a wall of enormous floodlights. They will serve nicely as the local sun.

The oven does not look at all like an oven. It is a silver-coloured barrel that is waist-high. The silver barrel has a stone core and is insulated with many layers of rock wool. On the top is a cooking plate. The oven is connected to an aluminium pipe that has a moveable aluminium parabolic dish on the other end.

”We’re capturing the sun here,” says Habtamu, pointing to the one-and-a-half metre parabolic dish covered with small mirrors. It works like this: the dish reflects the suns rays and focuses them on a fibre mat of polished steel wool. The mat is attached to the end of the pipe that connects the parabolic dish to the oven. It is the air that is drawn though this fibre mat that transports the sun’s energy to small stones in the centre of the oven that store the heat. The cooking plate makes contact with the stored heat via an aluminium plate that is fixed in the stones and carries the heat upwards.

WORLD’S FIRST • Habtamu is a PhD candidate at NTNU. The prototype oven he is now designing with other researchers at the Department for Energy and Process Engineering is the first that both collects solar heat and maintains cooking temperatures for more than 24 hours.

In Habtamus’ homeland, electricity is a luxury limited to the large cities. In rural areas, the solar oven opens the possibility of being able to cook food after sunset. It can warm a house, boil water and help to improve hygiene. The local hospital will see a dramatic improvement in its standards with sterile medical equipment. Currently, patients have to bring wood with them for heating water.

STORAGE IS THE PROBLEM • “The difficulty isn’t to get the oven to reach 400° C,” explains Habtamu, “but to store the heat. The oven has to maintain a temperature of 250° C for more than 24 hours after it is heated for us to be satisfied. That’s what is needed to cook food.”

Making something like this out of modern materials is easy, according to this researcher. The more difficult challenge is finding simple materials.

“We use high technology approximations to find the best combination of the simplest and most easily available materials. The technology can be developed so that it can be built on a larger scale for electricity production. The solar oven functions like an energy source that can be operated 24 hours a day. This could be the future’s most important energy source,” he concludes.

OUT OF POVERTY? • The solar oven is a result of a 10-year collaboration involving a number of African universities, the Norwegian Agency for Development Cooperation (Norad) and NTNU. This particular prototype is based on a concept developed by Actor Chikukwa from Zimbabwe, who was recently awarded a PhD by NTNU’s Department of Physics.

The physicist and the initiator of the research project, Jørgen Løvseth, believes that this kind of energy collector can help lift Africa out of poverty, without destroying the environment.

“This is all about taking underdeveloped countries and their challenges seriously,” he says. “First, people have to have food and heat, and a public health service that can sterilize its medical equipment. The solar oven can make an important contribution to that. We are developing a technology that will enable many Africans to develop their own communities, and lift themselves out of poverty. And all this, without affecting the environment. The technology also can be the foundation for small and large-scale industry.”

BURNING GLASS EFFECT • Professor Løvseth explains why this kind of oven has not already been invented. “The sun as an energy source has been used relatively little by the world. In most places, the sun could easily supply the demand for heating and with a little bit of development, the cooling demands as well. But the Industrial Revolution started in a place where there isn’t much sun and was based on coal, and later oil and natural gas. These energy sources are now creating a climate catastrophe, they’re shrinking in importance, and we have to think in new ways.”

“We can collect solar energy in two ways,” he adds, “via solar cells that make electricity, or as heat, as we’ve done in this solar oven. Concentrated systems that use heat need direct sun and provide a high temperature. We call it the ‘burning glass effect’. The heat can be used directly, for industry or in producing electricity. This is already being done in places where there is a lot of sun, such as California and Spain."

MORE EFFECTIVE THAN SOLAR CELLS • The project also involves measuring and analysing the sun’s light and radiation in different parts of Africa. The goal is to find the best places for large-scale solar heating equipment for national power stations in Ethiopia, Uganda and Mozambique.

“The direct use of solar heat is much more effective than the use of solar cells,” Professor Løvseth explains. “To use solar energy from solar cells, we have to go through a number of steps, and for each step we lose quite a bit of the original energy. If we could capture the sun’s energy in the Sahara in this direct way, there would be more than enough energy for 10 billion people consuming energy at the same level as the USA, and there wouldn’t be any CO_2 emissions.” ■

Preheat your oven might mean simply putting it out in the sun.

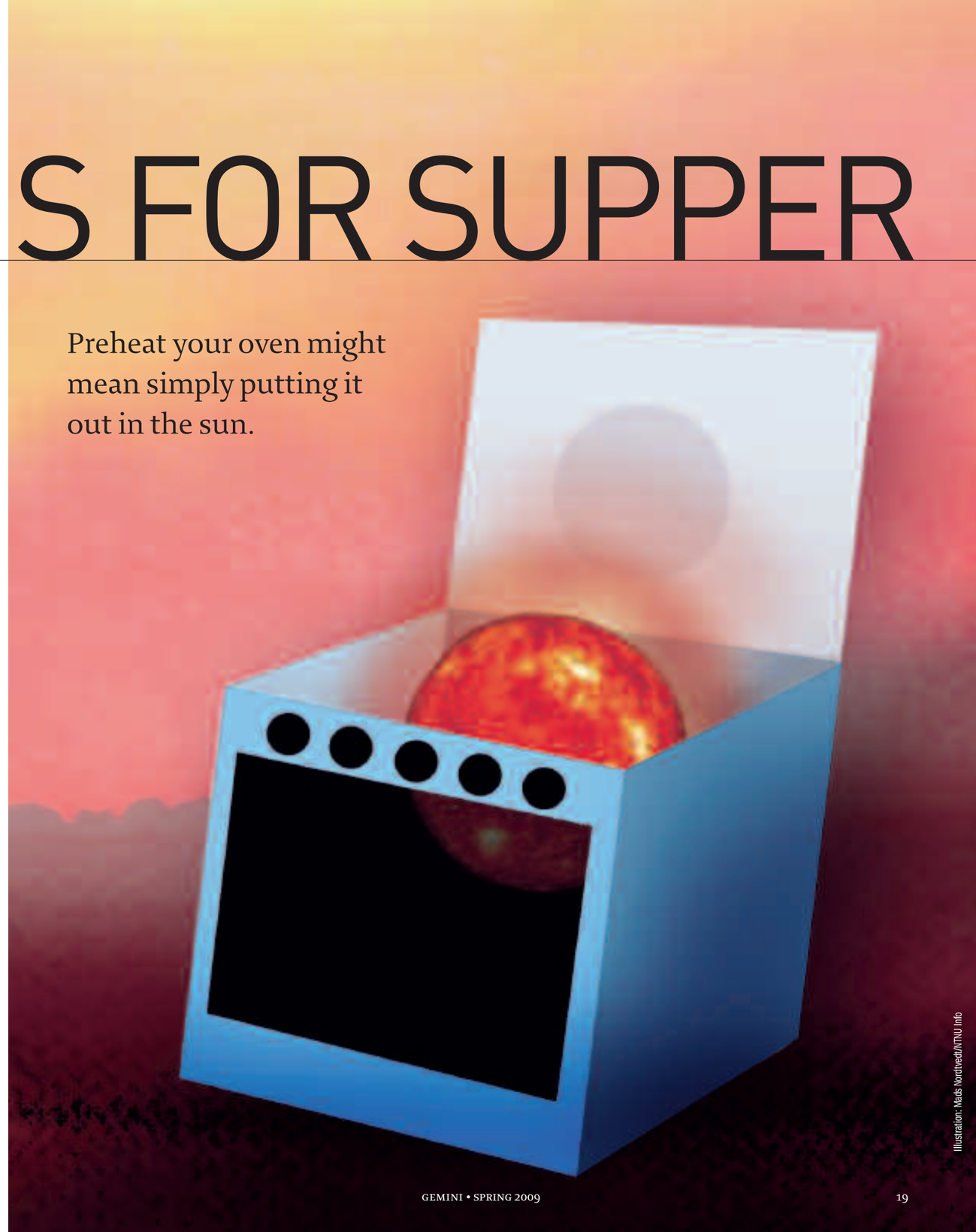


Illustration: Mats Nordtvedt/NTNU Info

Illustrasjon: Line Halsnes

Alzheimer's disease takes you into a deep darkness. But a laser light and a detective molecule will lead you out.

SECRETS OF FORGETTING

> "I believe in 5 to 7 years that we will have come a long way to explaining the mechanisms behind the development of Alzheimer's."
>
> Professor Mikael Lindgren

MEDICINE **BIOCHEMISTRY** • **PHYSICS**

BY: Tore Oksholen and Hege J. Tunstad
CONTACT: Mikael Lindgren, Department of Physics, NTNU
PHONE: +47 73 59 34 14 **EMAIL:** mikael.lindgren@ntnu.no

The mouse will die. It has Alzheimer's, which means that some protein molecules, slowly and without mercy, will change their structure and become fibrils – useless, thin threads. This process creates irreparable damage. But no one knows what, why and how.

Researchers have given the mouse this illness. But they have also created a tiny window into its small animal brain, through which they can send a special laser light.

The laser sheds light on a scene that to date has rarely been illuminated, and on a life and death drama. Previously, the protein molecule – the bad guy – had the stage all to himself. Now he will soon encounter competition. A young hero is waiting in the wings.

WHAT GOES WRONG? • The Alzheimer's puzzle is actually a whole series of riddles. But something links them, this protein that does so much damage on the road to becoming a fibril. What is it that goes wrong?

Proteins are made of small "building blocks" made of amino acid. The cells produce 20 different amino acids, which can be arranged in different ways to determine the kind of protein that we get.

The rows of amino acids that are created inside the cell are like threaded beads on a string that together create a pattern. The pattern is determined by the DNA code. When these strings of beads are combined, they go through a process of folding and forming before creating a protein with its final functional form.

Sometimes this process goes wrong. Misfolded proteins are an important part of the problem for many serious diseases: Alzheimer's, Parkinson's, type 2 diabetes, Creutzfeldt-Jakob, cancer, cystic fibrosis, and many more.

"We know that something fatal happens along the way. But no one knows in detail why, and how, and how the damage occurs in the process," says Professor Mikael Lindgren at NTNU's Department of Physics.

CAUGHT IN THE ACT • Researchers at NTNU and the University of Linköping are now at work on the development and use of a so-called molecular probe. This is a specially designed molecule that can be sent into the brain through the blood – a detective molecule, if you will.

Laser spectroscopy, as Professor Lindgren uses it, is all about hunting for the protein misfolding while it is still under way. The detective molecule is the hero in this drama. It changes colour when it finds the criminal. And the spectral frequency of this colour can be observed using a known laser light. Thus the once-darkened stage is brilliantly illuminated for researchers.

Researchers need this kind of help. Once the protein has become a fibril, it is no longer as harmful. The damage seems to occur during the protein's transition into a fibril. That is when the proteins clump together with other proteins to create a Gordian knot. This brings everything to a stop inside the cells, thus causing the symptoms of the illness. And that is why it is critical to catch the criminal red-handed.

SHUTS OFF VITAL FUNCTIONS • Today we know little about how these processes play out.

"We know that they eventually turn off some key functions in cells. One possibility is that the cell's 'recycling stations' are damaged or broken. It is these stations that break down unnecessary and damaged molecules and makes them into new things," explains Professor Lindgren.

"If the detective molecule adheres to the protein on the way to becoming a fibril molecule, and changes colour when it does, we can turn the searchlight onto it and follow it further," he says.

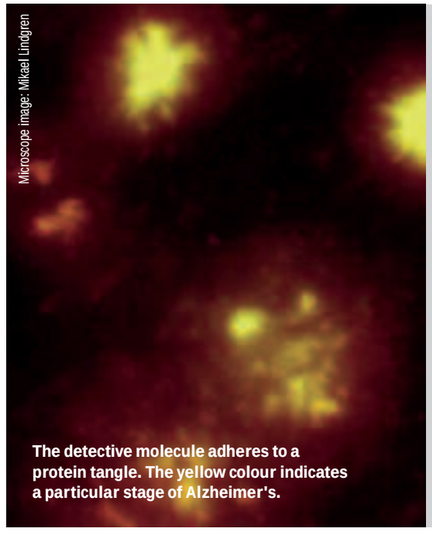
SEEING THE PROCESS IN COLOUR • The detective molecule is sent into the brain via the blood. It uses the brain's built-in transportation system, and passes through all of the brain's defences against intruders. Well inside the brain, it will not relax until it finds a misfolded protein and adheres to it.

When the scientists look with the laser, the detective molecule emits fluorescent light with specific colours. The spectrum can report both that the detective molecule has found its way, and how far the protein thug has come in its destructive process. Different stages of the disease light up in different colours.

"The beauty of the method is that we can follow the illness while it is underway, and learn how the process develops. This is a new approach," Lindgren adds.

"We are developing a colour image for the disease, so that we can compare it with what develops with medication. We can simply compare the colours of medicated and non-medicated situations over time, and see if different medicines have an effect."

The professor thinks this approach will provide a much better understanding of the processes in the illness, and could provide the key to finding out how it could be stopped and perhaps reversed.



Microscope image: Mikael Lindgren

The detective molecule adheres to a protein tangle. The yellow colour indicates a particular stage of Alzheimer's.

NEEDLE IN A HAYSTACK • Many researchers around the world are trying to find the causes of Alzheimer's disease, and in doing so, hope to find a cure. Most are doctors, while Lindgren is a physics professor who is working with biochemists, among others, to examine the problem from a natural science perspective.

As a physicist, Lindgren has worked with advanced spectroscopy over a number of years. But his interest in Alzheimer's comes in part from a personal experience.

"My mother suffered from Alzheimer's and died in 2001. Anyone who has experienced this disease at close range knows just how much pain and suffering it causes both in the person who has the disease and for everyone around. It was in this context that I decided to approach the disease from my professional point of view," he explains.

The researchers face a difficult task. There are just a few hundred protein fibrils scattered among a great number of other protein molecules. So looking for them is like looking for a needle in the proverbial haystack. And yet Professor Lindgren is an optimist: "I believe in 5 to 7 years that we will have come a long way to explaining the mechanisms behind the development of Alzheimer's."

CAN THE DISEASE BE STOPPED? • Once this new approach to characterizing Alzheimer's at the cellular level has succeeded, the trick will be to transfer the knowledge to human samples. But that will require finding an alternative to the window that researchers are able to surgically embed into a mouse brain.

The researchers have considered trying to make a magnetic probe. Thus, the detective molecule could be tracked through the brain by using magnetic resonance imaging. PET scans would also work but are much more expensive than MR.

"With this you can imagine that in the course of 5 to 10 years it will be possible to detect Alzheimer's at an early stage by using MR," Professor Lindgren predicts.

The next step will be to create drugs that stop the development of the illness. Once researchers have been successful in identifying the mechanisms that lead to Alzheimer's, it will also be possible to find a drug to combat it. ■

YELLOW ILLNESS, RED ILLNESS...

The detective molecule has a history that extends back to the 1980s. The starting point was something called conducting polymers, which were originally used for batteries, light emitting diodes, and other electronics.

Peter Nilsson, now an assistant professor at Linköping University, discovered several years ago that these polymers can also be used to identify specific protein structures. The polymers are the starting point for the detective molecule now being developed for medical research, in cooperation with various European scientists.

NTNU Professor Lindgren's specialty is the actual testing of the detective molecule, and creating the colour map that describes what the "detective" has found.

Yellow of a specific wavelength suggests Creutzfelt-Jacobs disease, while another yellow colour may indicate Alzheimer's. Different colours can also indicate a different stage of the disease, because the gradual progression of the illness alters proteins inside the cells. This, in turn is the reason for the different light wavelengths.

The process involves three steps, Lindgren explains:

"First, we test these 'detectives' – which we also call probes – completely alone with a laser. We learn to get to know them and find out how they react to and use fluorescent light with different wavelengths.

"Then we test how the probes stick to a synthetic variety of an illness molecule, and we develop colour maps based on these results. For Alzheimer's tangles, the most tightly braided proteins give a yellow light, while a little looser tangle gives more orange-greenish light. The colour phase depends on the type of detective molecule that is used.

"Finally, we send the probe into a living mouse, through an injection into its tail. When we send the laser light through the window in the mouse's head, we can follow the development of the tangles in the brain. In the future we will be able to do this in a person, but then we will have to use a paramagnetic detective molecule, so that we can follow the process through magnetic resonance imaging," says Lindgren.

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; &#. 0-*#+ '1 2& 2 2&#1# 1712#+ 1"-, =2 2#** 2&#. 30!& 1#05 &'!& -$2&# 5', "-515'** # + -12 #, 4'0-, + #, 2 **7 $0#, "*7 -4#0 ** -0 0# 5# 2-*" , 72&', % -32 2&# #, 4'0-, + #, 2 *#!-, -+'! !-, 1#/3#, !#1 $-01-!'#27 '$ 2&#. 30!& 1#0!&--1#1-, #5, "-50 2&#02&, 2&# -2&#0 &'1'1 5& 2 , ##"12- , 15#0 15#** 1.-11' *# -, 2&# 1'1-$2&#), -5*#" %# 2& 2'1 4'* *#<

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; #5'** & 4# 2- 1#2*'+'21 , " '"#, 2'$7 2&# #, 4'0-, + #, 2 *'+. !21 2& 25#!, .32 .0'!#-, -"-1-5#, ##" ', $-0+ 2'-, $0-+ ** + , 3$!230#01 0#% 0'", % %0#, &-31#%1 #+ '11'-, 1 2&# 31# -$!&#+'! *1 , " 2&# + -3, 2-$5 12# %#, #0 2#" -0#6 +. *# + , 3$!230#05 '** & 4# 2-! *!3* 2# , " 0#. -02 -, 2&# .#0!#, 2 %# -$0#!7!* *# + 2#0' *1 ', 2&#'0', 13* 2'-, . , #*1-00-$, %+ #+ 0, #1 &'15'**#, *# 312- #12'+ 2# 2&# "#%0## -$ #, 4'0-, + #, 2 **-"', %2& 25'** # %#, #0 2#" 75 12#', 2&# $3230#

2'12&# 0#1# 0!&#015&-5'**& 4# 2- "#1'%, 2&# 1203!230# 2& 25'**#, 130# 2& 2 ** 2&'1', $-0+ 2'-, 5'** # !-, 1'12#, 2 , " 4'* *# 2- #4#07-, # , !#'2'1', .*!# '25'** #.-11' *# 2-! ** 3. 2&# "05', %1-$ 3'*", %3, "#0 .*, , ', %!*!) -, .0-"3!2*#4#*, " "-5, *-" ', $-0+ 2'-, 13!& 1 & 2.0-.-02'-, 5'**#, "3. 15 12# -5+3!&#, #0%7 5 1 31#" ', 2&#.0-"3!2'-, .&1# & 25-3*", -0+ *#, 4'0-, + #, 2 *'*- " # $-0 3'*", % *#)# 2&'1 & 2'1+7.-2#, 2' *$-0+)', %'+ .0-4#+#, 21 , " *-5#0', %2&# #, 4'0-, + #, 2 * !-121-$+7 3'*", %<

½ž þ² þ -"7 #', %#, 4'0 -, + #, 2 **7 5 0#', 4-*4#1!-121 2'1"'$$!3*2 2-+-2'4 2#!-+. , '#12-"-.2+# 130#12& 2 5'** 30, &-*#1', 2&#'0. -!)#21 322&# %0-3. -$', 4#12'% 2-01 #&', " 5 , 21 2-!&, %# **2& 2

&#7 0# #4 *3 2', % 1712#+ 13%%#12#" 7 #**-, 5&#0# 7 2&# #, 4'0-, + #, 2 *!-121 0# ', !*3"#" ', 2&#. 0'!#-$!-, 1203!2'-, + 2#0' *1 "'0#!2*7-0-$!-+. *#2# 3'*", % &#0# 2&# '+. !2'1*# 12 2&#. 0'!#5'** #*-5#12 #**-, =1 * $ 012" #+. & 1'$#1 2& 2 2&# '+ '12-'"#, 2'$7 2&#. -2#, 2' *, "!0# 2# 1712#+ 2& 25'** +)# + , 3$!230#0 0#1. -, 1' '*27. -11' *# , " ', 5&'!& -2#, 2' *. -**3 2'-, '1#12'+ 2#" , ". '" $-0', "4, !# ; $5# 0# %', % 2- # !-, 1'12#, 2 5 &#0# + , 3$!230#0 0#1. -, 1' '*27 '1!-, !#0, #" 2&# !-, 1203!2'-, 1#!2-05'** & 4# 2- # ', 4-*4#" , " 5'** & 4# 2- !!#. 2 + 3!& %0# 2#0- *% 2'-, 1 , " 0#1. -, 1' '*27 2& , !300#, 21!&#+ #1 ', 4-*4#<1 71 0 12" ; &#, '!# 2&', % -32 '1 2& 2 3'*", %-5, #01 , " !-, 1203! 2'-, + 2#0' *1 13..*#01 & 4# ##, . 02-$ ** 12 %#1-$2&#. 0-(#!21-$0 1'+. -02, 20#$#0 #, !# %0-3. 1 &'1 1&-3* &#*. 2-1'+. *$7 2&# $-**-5', %. & 1#1<

&# !-121-$#, 4'0-, + #, 2 *"- "1 ! , # 11'%, #" 2- 2&# 3'*", % + 2#0' *1-0 2&#'0 .0-"3!#01 2- 2&# 5&-*# 3'*", %-0 3'*", % -5, #0-0 # *',)#" 2- 2&# 31#-$2&# 3'*", % -0'21 31#01 32'$2&# !-, 1203!2'-, ', "31207 1 5&-*# '1 2- 4-'" , #2', !0# 1#', 26 2'-, 2&# !-121!-3* #. '", 2- $3, " , " . '" -32 %', 2-5&-#4#0!, "-!3+#, 2%--"5 12# 20# 2+#, 2.0-!#11#1

; &'15-3*#, !-30 %#', "31207 2- "-.2 #, 4'0-, + #, 2 *+# 130#1+3!&+-0# 0.'"*7 2&, 5# & 4# 1##, 3, 2*, -5< #"#4#1 0'12', -*2&#

(+9 ?9,5(5+ 809:05 63:/, # $;03+05. (5+ 5-8(9:8;*:;8,),30,<, $ =033,5*6;8(., 05+;9:8?:6(+67:,5<08654,5:(34, (9;8,94;*/ 468,8(70+3?:/(5=, /(<,9,,5;5:03 56=

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@ $ 09(5" 7861,*::/(:096=5,+)?#5A/,::((5+3,+)?# $;03+05. (5+ 5-8(9:8;*:;8, :8;59-864 ;5:03 (5+/(9(;+.,:6- 4033065

@ 30:5,09-;5+,+)?$/, ",9,(8*/ 6;5*03 6- 68=(?(5+:/, ;9,8 +80<,5",9,(8*/)(9,+ 556<(:065 786.8(44,

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, #, 4'0-, + #, 2 *'+. 0'+ 230'1 #%', , ', %2- # + 312', 2-" 7=1 1-!'#27 (-0.3*!1#!2-0 3'*", % -5, #01 *)# 2 21 7%% 5'1& 2- .0#1#, 2 , #, 4'0-, + #, 2 **7 $0#, "*7.0-$'# 1"-&-2#*!&', 1 13!& 1 &-, -2#*1 -02& 2 2&#7 + 312 & 4# "-!3+#, 2 2'-, 2& 2 !, 2#** 2&# 5-0* 2& 2 2&#7 & 4# + "#!&-'!#1 2& 25'** #, #$2 2&# #, 4'0-, + #, 2

*# 312 41#, 2 , :&#22 *1- #*#4#1 2& 2!-, 13+#01 2-" 7 5'** "#+ , " + -0# -$ 2&# !-, 1203!2'-, ', "31207 5&#0# #, 4'0-, + #, 2 **7 $0#, "*7 , " #, #0%7 #$$!'#, 2 1-*3 2'-, 1 0# !-, !#0, #"

; &#!*+ 2# !0'1'1', -2%-', %2-"'1..# 0 -4#0, '%&2 , " 1& 0. #0$-!31-, 1312', '* '27', 2&'1 1#!2-05'** #!-+#+-0# , " + -0# '+. -02, 2 ! , -$$#0 2&# !-, 1203!2'-, 1#!2-02&# .-11' *'27-$)##.', % &# " -$2&# "#+ , "12& 2 0# 130# 2-!-+#<&# 1 71

&# '+'12-*3, !& !-+.*#2# .!) %# 7 2&# #, " -$ &# 3'*", % #1# 0!& 1!'#, 2'121 $#*2& 2 2&# .0-!#11 '1 *0# "75#*3, "#05 7 "1 71#, #*#4#1 2& 2.3*!1#!2-0-5, #01 5'1& 2- & 4# !-, !0#2# $%30#1$-02&#'0 3'*", %1 2& 2!, "-!3 +#, 2 2&#'0#, 4'0-, + #, 2 *.#0$-0+ , !# , " .0#$#0 *7 "#+-, 120 2# , , 3 *'+.0-4# + #, 21 -05 7, ##"1 , ', "'! 2-0-$%-*1 0# !&#" ', -0*#02-+)# -2& .#0$-0+ , !# , " , , 3 *'+.0-4#+#, 21 4'1' *# ; #0# 2--2&# , 15#0!-3* # < 171 -*2&#

; 32&-50# 7-3%-', %2-%#2 2&'1 1#2-$ 2--*1 "-.2#" <

; &#+#+ #01-$2&'1.0-(#!2"-, -2& 4# +, " 2# 2-" #!'" # 2& 2 ** 2&'1 1&-3* # *3, !&#" # +312 & 4# #'2&#0 %0##+#, 2 5'2&', 2&# 1#!2-0'21#*$2-"-.22&# 1712#+-0 2&# 32&-0'2'#15'** & 4# 2-0#/3'0# 2&#', "31 207 2-"-1- 7'113', %%#, #0*0#/3'0#+#, 21 1#2-32 7 2&# ', '1207-$2&# , 4'0-, + #, 2 -0 2&# ', '1207-$-! * -4#0, +#, 2 , " -30 4#07 2&', %"#.#, "1-, 5&'!&+-"#* '1!&-1#, <!-, !*3"#1 -*2&#

¾ × ¾þ ½ž ½– ³⁄₂⁄₂ ½² Ž¾ ½þ ³ ¦ ¾ ³

1¾ Þ² Þ ²¾ ³ , 0-, "&#'+ #), - 7%% , 20#. 0#, : 0 '1 3'*", % !-+ ', #" !-+ + #0!' * &-31', % , " -$$!# *-!) 2 #"0# *4#& 4, &'1'1-, # -$2&0## !300#, 2!-, 1203! 2'-, .0-(#!21 -05 7 2& 25'** !-, 20' 32# " 2 2- 2&# 1712#+ ; # 0# #, 2#0', % " 2 -, ** 2&# + 2#0' *1 5#31#<171 -0# ** , " -$ #), - 7%% , 20# .0#, :0;5&#2&#0'2'1. ', 2!-, !0#2#-02'+ #0< ** , " + #, 2'-, 1 2& 2 2&# !-+. , 7'1 31', % !-+.32#0.0-%0 + "#4#*-.#" 7 -0!-, 13*2 , $-0+ 2'-, 712#+1 2-! *!3* 2# 2&# !-12-$!-, 1203!2'-, .0-(#!21 &# 1-$25 0# & 1 ##, #62#, "#" 2- **-5#, 4'0-, + #, 2 *. 0+#2#01 13!& 1 #+'11'-, 1 , " *$# !7!*# !-121 2- ##, 2#0#" ; 7#, 2#0', %0# *4 *3#1 5#!, 1## 5&'!& .0+#2#01 1&-3* #%3'", %31 , " 5 & 2'2 5-3** + # , 2-.*!# , #, 4'0-, + #, 2 *2 6-, !#02', .0-"3!21<

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