Chapter 5

In the Dutch mountains

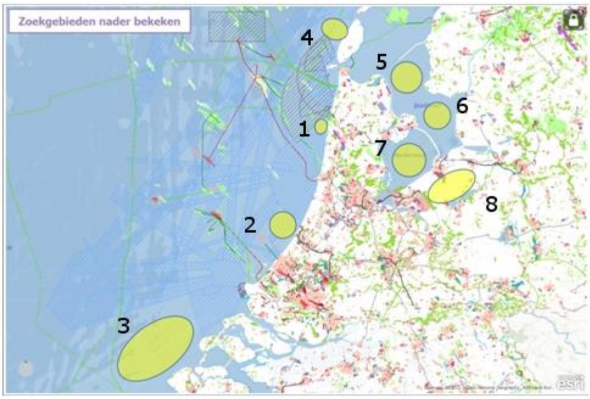
Bartels Consulting Engineers came to the study group with the wildest idea: building a mountain of two kilometers somewhere in The Netherlands. Could the mathematicians find a good location? And could this giant mountain be sustainable?

"Our country is flat. Booooooring flat", wrote journalist and former professional cyclist Thijs Zonneveld in the summer of 2011. "It's a crazy idea. I know. But the more I think about, the more I like it. I want a mountain. A real one. In the Netherlands." His crazy idea was picked up and soon many people were enthusiastic about building a mountain in The Netherlands. Tourists could go there for a day of skiing, Dutch athletes could do altitude training at home and cyclists would finally have a serious climb in this country.

A group of many companies joined forces in the organization "Die berg komt er!" (The mountain will be there!). They started investigating the feasibility of building a two kilometer high mountain somewhere in The Netherlands. One of these companies is Bartels Consulting Engineers, responsible for many big engineering projects such as the excavation of the Stedelijk Museum in Amsterdam. Bartels Consulting Engineers came to the Study Group with a list of questions about the mountain. Where should the mountain be built? What materials can be used to build a mountain? Can the mountain be sustainable?

Moniek Vrielink, communication and marketing advisor at Bartels, was not sure at the beginning whether their company could formulate a question for the study group: "Our idea was so new, we did not have clear practical problems such as Tata Steel. But the organizers were so enthusiastic about working on the mountain, so we started discussing. And a week later we had thought up the questions for the study group."

Location, location, location



The eight locations for the mountain as suggested by Bartels.

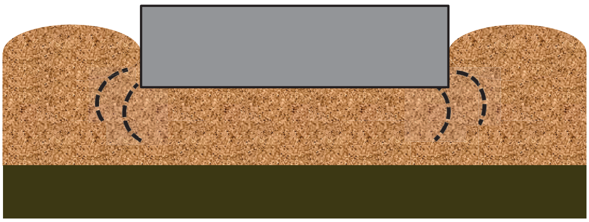
First things first: the mathematicians started by picking a location for the mountain. They considered the eight locations that were suggested by Bartels. Two of these locations were on busy flight routes to Schiphol, which is not a very good place to put a mountain. Two other locations would hinder ship traffic to Rotterdam or the IJsselmeer, so they were out too. For the four remaining options the study group considered sea currents and the impact on both nature and society. The only locations that did not immediately raise objections were location 1 in the sea near Bergen aan Zee and location 8 on land in Flevoland.

Layering

What is the effect on the soil of building a mountain? It is quite well known when and how soil will slide if a huge building is placed on it. But a mountain of two kilometers easily dwarfs the tallest man-made structure; the Burj Khalifa in Dubaj which is 830 meters. A mountain also has a different shape and will be much broader at the base than a building of the same height. Therefore the traditional models for soil mechanics can not be used. Just dumbly plugging in the data would for instance result in a sliding zone of several kilometers deep. But at this depth the soil might contain rock and the computations would not make any sense.

Therefore the study group developed a new model to give a rough estimate of how far the mountain would slide into the soil. They modeled the mountain as a solid cone that is mainly made out of concrete. Their rough estimate for the basis of the mountain is 150 square kilometers, which is larger than the entire Disney World area. The mass of the mountain would be around 6,9 trillion kilos (which has an impressive twelve zeroes).

The soil was modeled in four layers. The upper layer is very thin compared to the others and therefore neglected. The second layer consists of clay and sand and its thickness depends on the location. In Flevoland, the remaining land-option for the mountain, this layer is about half a kilometer thick. The third layer is also formed of clay and sand, but it is much more compressed from the pressure of the layer on top of it. Underneath this layer is the fourth and final layer which mainly consists of limestone. To simplify calculations, the study group combined these last two layers in their model as one rigid layer. So their model consisted of a mountain, a mobile layer and a rigid layer.



Two layers of soil and a mountain. To simplify calculations the mountain is taken to be a cone with a base area of 150 square kilometers and a mass of 6.9 trillion kilo. When the mountain sinks in the ground, a ring of soil around the mountain will be pushed up.

Slowly sinking in

In this simplified model the mountain sank eleven meters in the soil. This will push the soil around the mountain upwards. The amount of soil that gets displaced is a staggering 1.7 billion cubic meters. The mathematicians calculated that this would amount to a ring-shaped area from up to three kilometers away from the mountain rising eleven meters upwards. This would be a disaster for all the houses, roads and other existing structures in this area. The study group considered putting the mountain on pillars or making the mountain from a material that is less dense than the soil. However, both methods seem impossible to implement with current technologies. Therefore the study group concludes that it is best to build the mountain in the sea, where the effects of displacing soil will have less impact than on land. So they decide that Bergen in Zee is the best location for the mountain.

All the concrete in the world

How much material would be needed to build the mountain? In high-rise buildings roughly thirty percent of their volume consists of structural elements such as walls and pillars. But of course there are some huge differences between a mountain and a building. A mountain should have a useful exterior, but for buildings it is mostly the inside that counts. There is also the different shape: in high-rise buildings the height is much larger than the width, but for the mountain this will be reversed. For lack of more data, the study group decided to stick to thirty percent of the total volume as the estimate for the materials in the mountain. This would amount to a whopping thirty cubic kilometers of material. If the mountain were made from concrete, the amount of concrete needed would be four times the yearly worldwide production. This would give a carbon footprint equal to 350 years of Dutch emissions. Even with the faster-to-manufacture plastic it would take 29 years to produce enough material (where we again assume we may use the total worldwide production).

The mathematicians conclude that a man-made mountain can not be built using traditional construction materials.

Step by step

The study group also looked at the suggestion from Bartels to build the mountain in stages. One could start with a little hill and gradually expand the hill into a mountain. The mathematicians warned that in this process inevitability a slow-down would occur. If the mountain is made in the naïve way by adding layers to a hill, the slow-down will be at the end. Beginning with one cubic kilometer of material might make a hill of roughly 450 meters. Adding the same amount of material would add 121 meters and increase the height to 571 meters. But at the end, if there is 99 cubic kilometers of material already in the mountain, adding another cubic kilometer will only give an extra height of 8 meters.

Good news

In their presentation at the end of the Study Group the mathematicians summarized all these impossibilities of building a mountain. But then they smiled and continued: “Now the good news, suppose there is a mountain. How can we make it sustainable?” The goal was to make the mountain a zero energy construction: to have a zero net energy consumption and zero carbon emissions.

Vivi Rottschäfer from Leiden University explained that is was fun to brainstorm about this: “We could think differently than an architect. The inside of a building has to be useful. We could do other things. A wind expert also emphasized we should think of different usages. The Amsterdam Arena makes more money from concerts than from soccer games.”

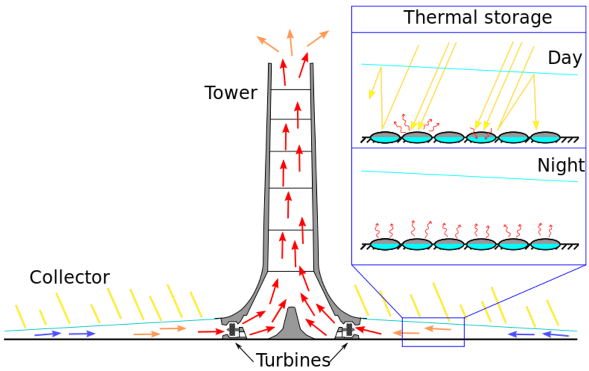
The answer is blowing in the wind

They focused on means of generating energy that exploited the height of the mountain. The wind speed at two kilometers altitude is for instance twice the speed at sea level. The energy that a windmill generates depends on the third power of the wind speed. So twice the wind speed means eight times more energy.

Wind tunnels would be another great way for producing energy on a mountain. Long narrow tunnels suck in air, similarly to a chimney. With a tunnel the wind power can be increased approximately five times. Combining the height of the mountain with tunneling it seems that a turbine could harvest thirty to forty times more power than a traditional windmill at sea level. However: the current turbines are not built to withstand these higher wind speeds, so new ones would have to be developed.

Sunny days

Solar panels are not more efficient at a greater height, but their advantage is that they can be installed in places that would not be used otherwise. One could also think about solar chimneys. These consist of a glass roof, a chimney, and wind turbines. Sun heats the air in the chimney through the glass roof and the warm air rises in the chimney. This will generate high wind speeds, which can generate wind from turbines. A single solar chimney of one kilometer high can provide energy for thirty thousand Dutch households. The great advantage of solar chimneys is that all the necessary technology is available and relatively cheap. The main problem with them is that people usually object to a huge chimney in their neighborhood. But when the chimney is built into an enormous mountain this will be a minor problem.



A schematic view of a solar chimney.

The mountain will be there

Even though the mathematicians concluded that with current technology it is not possible to build the suggested mountain, Moniek Vrielink remains optimistic. “Nothing is impossible. Many people are thinking about other ways to make a mountain. Companies that normally compete against each other all join forces in this crazy idea.” It will take at least until the end of 2013 to finish the feasibility study. But the concerns of the mathematicians are taken into account. The current building plan is to start at 300 meters and go from there in steps of 300 meters to a final height of 1200 meters. Vrielink: “That way we would only need an area of six by six kilometers on the ground.” They are also studying the further possibilities of solar chimneys and were very happy with this suggestion.

Thijs Zonneveld remarked at the presentation of the final report that the mountain is an innovation catalyzer. It generates tons of new ideas. Vrielink is confident about the long-term view: “The mountain will be there.”

Team

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