2050：能源的征程

2050: AN ENERGETIC ODYSSEY

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背景介绍

2015年12月12日，在法国巴黎联合国气候变化大会结束后，195个国家和地区通过并签署了具有历史性意义的《巴黎协定》，庄严承诺将全球平均气温较工业化前水平升高幅度控制在2℃以内。这是一项巨大的挑战，因为我们只有将现有碳排放量减少80%~95%才能达到这一目标。虽然人类早已意识到大量排放二氧化碳的危害，但我们的表现与在前照灯下受了惊吓而呆立不动的兔子无异。我们需要重新构想，将风险转化为机遇；我们需要重设愿景，勾勒一幅可能实现的未来蓝图，给予我们方向与希望。

为实现欧盟制定的目标，我们需要用碳中性能源完全替代化石燃料，这一转变并不容易，且将对社会产生诸多影响。改变使用化石燃料的习惯非常困难，因为化石燃料储备并未枯竭。换句话说，问题不在于化石燃料（碳氢化合物）的短缺，而在于其燃烧会排放二氧化碳。

北海地区具有大规模捕获风能的地理优势，也是整个欧洲最重要的区域之一，因此，这里成为了决定可再生能源战役成败的关键性战场。但北海并不是空无一物的，相反，我们的故事正是以此处世界上使用强度

最高的沿海水域为背景展开的。在这里，渔场与航运航线交错横贯，划定的自然保护区、军事区分布其中，摩天大楼般的海上油井高高耸起，数不清的油气管道穿行而过，几座风电场也已初具规模。另外，北海还需承载周边工业产业排放的污染与余热。

全新的区域能源系统

“2050：能源的征程”项目将北海周边区域整合起来。通过区域合作，我们将逐步建立起一个以北海为核心的全新的区域能源系统。通过这一过程，我们将展示如何在35年时间内，将污染型的化石能源系统转变为基于可再生能源的全新区域系统，而这些都离不开区域间的合作。

该项目建立起一系列主要的实体组成元素。项目首先将在场地内建造几座风电场，经由电缆输送其生产的电力。来自各个风电场的电缆汇集到海上中转站，由一条接岸电缆输送至海岸，最终汇集到一处能够对电能进行转化利用的登陆点。其次，场地中目前用于传输天然气的管道走廊，今后也可以用于将二氧化碳传输至地下存储设施。此外，还将建设港口与工业园区，以生产、组装风力涡轮机组件并将其运输到海上。该项目还

DOI:10.15302/J-LAF-20170407 | 收稿时间 RECEIVED DATE / 2017-07-27
中图分类号 / X24, TU98
文献标识码 / B

摘要

“2050：能源的征程”是一项针对西欧北海及周边地区的设计性研究，主要探究在该区域大规模开采、运输和储存可再生能源的可能性、机遇和空间影响。该项目展示了北海在实现《巴黎协定》中经全球通过的“将全球平均气温较工业化前水平升高幅度控制在2℃以内”的目标中扮演的角色。

欧洲承诺，截至2050年，将实现温室气体减排80%~95%。受2016年荷兰鹿特丹国际建筑双年展委托，H+N+S景观设计事务所与Ecofys能源与气候咨询公司、Tungsten Pro多媒体制作公司联合推出了基于可再生能源利用的北海区域规划。该规划概述出项目未来可能的实际情况，及其对自然、渔业、港口发展、经济和娱乐休闲的影响。

关键词

北海；气候变化；沿海；能源；海上风能

ABSTRACT

“2050: An Energetic Odyssey” is a research by design on the possibilities, opportunities, and spatial implications of the realisation of large-scale harvesting, transportation and storage of renewable energy sources on and around the North Sea. This project demonstrates the role the North Sea could play in meeting the globally agreed two-degree target.

Europe has committed to reducing green house gas emissions by 2050 by 80% ~ 95%. Commissioned by the Internationale Architectuur Biennale Rotterdam 2016 (IABR 2016), H+N+S made a plan for the North Sea together with Ecofys and Tungsten Pro, in which renewable energy sources are utilised. This plan outlines how that might look in practical terms and what the effects might be for nature, fishery, harbour development, economies, and recreation.

KEY WORDS

North Sea; Climate Change; Coastal; Energy; Offshore Wind

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- 北海地区之新愿景
- A new perspective on the North Sea

项目地址： 欧洲北海 项目面积： 750 000km² 项目委托： 荷兰鹿特丹国际建筑双年展、荷兰经济事务部、冯·奥德集团、壳牌石油、荷兰国有电网公司、泽兰海港、欧洲气候基金会、莱茵能源集团、Natuur & Milieu公司、鹿特丹港、阿姆斯特丹港 项目团队： H+N+S景观设计事务所、Ecofys能源与气候咨询公司、Tungsten Pro多媒体制作公司 设计时间： 2015-2016年	LOCATION: North Sea, Europe AREA(SIZE): 750,000 km² CLIENTS: The International Architecture Biennale Rotterdam (IABR), the Ministry of Economic Affairs, Van Oord, Shell, TenneT, Zeeland Seaports, European Climate Foundation, RWE, Natuur & Milieu, Port of Rotterdam, Port of Amsterdam PROJECT TEAM: H+N+S Landscape Architects, Ecofys Consultancy, Tungsten Pro DESIGN PERIOD: 2015 - 2016

计划在多格沙丘附近增设一座人造岛屿，并在此组装涡轮机，使组装点最大限度地靠近目标建设点。

一步步实现目标

北海周边六国——英国、挪威、丹麦、德国、比利时和荷兰——每年的能源消耗约为5 500太瓦时。为实现到2050年温室气体大幅减排，可再生能源将发挥至关重要的作用，并将承担至少75%的能源供给。这一宏伟目标的达成，不仅需要在清洁能源生产方面实现质的飞跃，还要求最大程度地减少能源消耗。

但是，我们可以将这一巨大挑战拆分成一个个阶段。目前，北海周边国家每年已有8%~9%的能源消耗（约500太瓦时）来自可再生能源。在第一阶段，节能问题应成为欧洲地区的重要议题。生产、转化和传输过程中存在不可避免的能量损失，因此我们每节约1兆瓦的能源就意味着减少了多达3兆瓦的能耗。节约能源是迄今为止最划算的减排策略，因为其效益高达三倍。因此，我们将标准设置得尽可能高，并设立了相较于2015年减排30%（至少节约1 500太瓦时）的目标。然而，我们也必须考虑到，到2050年，可能许多领域（如采矿、重型运输、钢铁生产等）仍需要依赖化石燃料产生的能源。但预计每年仅需900太瓦时的化石能源即能满足整个北海地区的需求。

研究表明，每年依靠近海风力发电输出1 200太瓦时的能源是可行的，且能够满足北海周边国家多达90%的电力需求，约占能源需求总量的三分之一。通过区域合作，北海有可能成为欧洲能源转型的中坚力量。

鉴于这一关系到整个欧洲的大型项目的规模范围和时间跨度，其必将成为孵化创新的沃土：包括开发新材料、增大风力涡轮机尺寸、研发便捷地维修海上涡轮机和在北海更深海域使用漂浮式风力涡轮机所需要的技术等。为捕获风能，基础性技术创新出现的速度将超乎我们的想象。所有这些创新和规模经济将大幅降低风力发电的平均成本。最

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2. 北海空间利用现状
3. 大气中二氧化碳的聚集情况
4. 北海地区风力充足，因而能够大规模生产风能。

2. Current spatial claims of the North Sea
3. Concentration of carbon dioxide in the atmosphere
4. Due to the abundance of wind on the North Sea, energy can be produced on a grand scale.

终会出现一个临界点，在临界点之前，达到这一目标的耗时总是比想象中更长，而一旦达到临界点，后期变化的速度又将会比想象中快很多。

兼顾生态保护

对项目运行过程的精心规划与设计，能够确保最大限度地保护北海的海洋生态。大约25 000座风能塔与水底石质结构上堆叠着人工礁石，可吸引各种海底动植物附着其

上。通过采用最先进的打桩技术和基于重力的解决方案，能够大幅降低施工过程带来的负面影响，确保海洋哺乳动物的迁移路线不会受到干扰。如果将风电场建设与禁捕区、海洋保护区的设立结合进行，将会产生一种良性的协同效应。

最后，在空间规划方面，风电场的选址充分考虑了鸟类的迁徙路线。因为鸟类会通过最靠近海岸的区域来确定方向和位置，所以这一区域应尽可能维持现状。此外，如果雷达探测到候鸟群经过，风电场也可以短暂

停止运行。

通过精心规划，海岸上游客的视野不会受到影响。该项目位于距海岸19km之外的区域，即使在晴朗的天气情况下，地球曲率也能使涡轮叶片顶端产生的白雾不会被轻易看到。

促进就业

即使面临人口密度较高、存在程序性障碍，以及可能存在的邻避效应等不利因素，通过北海六国之间或大或小、或集中或分散的行动与合作，也将有望完成剩余1 400太瓦时可再生能源的目标——太阳能、水能、风能、地热、生物质与潮汐等都可能成为项目的潜在能源。

但这样的数字仍然是抽象的，具体来说，这意味着到2050年，我们将需要安装大约25 000台风力涡轮机，平均发电量达10兆瓦，并形成57 000km²的覆盖网络，这就意味着平均每周需要安装15台涡轮机。我们无

疑需要从一个非同寻常的尺度来思考问题。这项巨大的工程无论在规划、资金、设计和实施方面都需要付出极大的投入。

这一宏伟的项目将为欧洲经济发展提供重大机遇。由于需要生产制造专门的船只，北海周边现有的港口设施也面临着极大的提升需求，甚至迫切需要扩建港口。在这种合作模式下，北海的风能系统将迅速达到临界目标，突破临界点后，区域合作将从线性互连转变为网状结构，效率也将大幅提高。

该项目将对就业产生积极而显著的影响。供应链的各个层面和各个阶段将为拥有不同技能的工人提供工作机会，带来蓝色经济的增长。最重要的是，北海能源采集项目将产生预计31万个工作岗位，远超过因海上化石燃料产业削减而取缔的28万个工作岗位。

通过深度合作提供支持

当我们回到现实，面对日常的政策环境，上述愿景能否实现？我们有充足的理由

认为它是能够实现的。在文化领域，对于这一设施的交互式生产催生了一个由诸多关键性参与者合作完成的复合体。这是设计师、科学家，以及由建造师、海岸带专家、政府部门、能源公司、传输系统运营商、港口当局和自然非政府组织的专家结成的联盟密切合作的结果。若想让上述愿景成为现实，只有为市场这只看不见的手带上“绿色手套”——根据实际情况对二氧化碳进行定价或征税。唯有在坚定不移的政治路线指引下的企业化状态，才能推动能源社会的实现。

作为未来绿色经济的基础，这一对于北海的展望很可能成为现实。区域合作使我们能够在大规模获取绿色能源的同时，兼顾生态系统的改善。我们已经突破了想象力这一难关。

自古以来就贡献卓群的北海，未来也将成为社会中深度脱碳的支点和共同繁荣的源泉。**LAF**

- 5. 开发海上风能：北海地区的目标是在2050年达到300吉瓦的装机容量。
  - 6. 已投入使用、正在建设中或拟建的海上风电场的平均水深和离岸距离。气泡大小代表风电场的发电总量。新的风电场被设置在离岸较远的深水处，且规模更大。
  - 7. 图上的25 000个小点代表将在2050年之前建成的25 000座风力涡轮机。
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- 5. Development of offshore wind: in the scenario for the North Sea, the aim is 300 GW of installed capacity by 2050.
  - 6. Average water depth and distance to shore for online, under construction and consented offshore wind farms. Bubble size represents the total capacity of the wind farms. New wind farms are planned in deeper water further from the coast and are also increasing in scale.
  - 7. The 25,000 dots, representing 25,000 wind turbines which need to be installed by 2050.

Background

In Paris on December 12, 2015, at the end of the United Nations Climate Change Conference, a historic agreement was signed in which 195 countries solemnly promised to keep the global rise in temperature “well below 2°C.” The Paris agreement constitutes a stunning challenge. We need to reduce our carbon emissions by a staggering 80% to 95% to reach that goal. We are long well aware of the risks of belching out CO₂, but we seem petrified as rabbits caught in the headlights. Risks alone will not get us into action. We have to reframe. We have to exchange the frame of risk for the frame of opportunity. And for this we need new “imaginaries,” images of a future that can work, that gives us perspective and hope.

Reaching the European Union’s target requires nothing less than a complete transition from fossil fuels to carbon neutral energy sources, a transition that will not be easy and that will have repercussions at every level of our society. Overcoming the fossil fuel habit is going to be even tougher because reserves have not yet been depleted. In other words, the problem is not a shortage of hydrocarbons in the ground, but rather an excess of carbon dioxide in the atmosphere.

The North Sea is an area where wind can be harvested on a grand scale and is one of the crucial areas in Europe where we will win or lose the battle for renewable energy. But the North Sea is not empty. Our story is set in the most intensively used coastal waters in the world. With fishery and shipping routes cutting right across, it contains designated nature reserves and military zones, oil rigs as the size of skyscrapers, countless oil and gas pipelines and there are already several wind farms. Moreover, the North Sea is used as a sink for pollutants and residual heat from our industries.

A New Regional Energy System

In “2050: An Energetic Odyssey,” the North Sea will bring the region together. Through regional cooperation, we will step by step develop a new regional energy system that has the North Sea as its heart. And by doing so, show how we can move

from a polluting fossil energy system to a regional system based on renewables, within a timespan of 35 years. And all of it based on a regional cooperation.

We developed a series of main physical components. First of all, there are wind farms with cables transporting electricity. Cables from the wind farms converge at the connectors on the sea, which are led to the coast by a landing cable, ending at a landing point where the electricity can be tapped. There are also pipeline corridors that currently transport gas and will subsequently take carbon dioxide to underground storage facilities. In addition, the ports and industrial estates where wind turbine components are manufactured, assembled, and shipped out to sea. In order to situate the assembly point sufficiently close to the building site, an additional construction island is planned in the vicinity of the Doggersbank.

To Achieve the Goal Step by Step

Together, the North Sea countries — the United Kingdom, Norway, Denmark, Germany, Belgium and the Netherlands — annually consume approximately 5,500 TWh of energy. In the context of substantial greenhouse gas reduction by 2050, renewables play a pivotal role and would need to supply at least 75% of all the energy that we consume. This is a very ambitious goal that requires a quantum leap in clean energy production and the maximum effort in terms of energy saving.

But we can unravel this enormous challenge bit by bit. Currently, 8% ~ 9% or approximately 500 TWh per year of the energy consumed by North Sea countries already comes from renewable sources. First of all, energy saving needs to be high on the European agenda. Every megawatt

8. 北海各国的最终能源生产总量

9. 北海各国的最终能源需求总量

10. 分阶段实施过程
8. Final energy production of the North Sea countries

9. Final energy demand of the North Sea countries

10. Staged implementation

2020

2030

2040

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we save means a whopping 3 MW less production due to inevitable losses during production, conversion and transport. So saving energy is by far the most cost-effective reduction strategy because its effect is tripled. That is why we are setting the bar as high as possible and stating that a 30% reduction — a saving of no less than 1,500 TWh — relative to 2015 has to be attainable. At the other end of the spectrum, we have to take account of various sectors for which there will still be no alternative to fossil fuels by 2050, like mining, heavy transport, steel production, etc. We estimate that some 900 TWh per year will suffice for the North Sea region.

Our research indicates that it is feasible, with the right ambition, to generate 1,200 TWh of electricity per year by offshore wind. This will provide a dazzling 90% of the total electricity demand of the North Sea countries and roughly one third of the total energy demand. Through regional cooperation, the North Sea could become Europe's energy transition's biggest asset.

Due to its scale and timeline, this European mega-project will be a breeding

ground for innovation; development of new materials, ever increasing wind turbines size, technology required to facilitate maintenance of turbines at sea and floating wind turbines in order to utilize deeper sections of the North Sea too. The mission drives the innovation. Sooner than we imagine, fundamentally new technologies will emerge for harvesting wind energy. All these innovations and economies of scale will drastically reduce the levelled cost of wind energy. This price will be the tipping point between the observation that things always take longer to happen than you think and then they happen much faster than you think they could.

Alignment with Ecological Protection

Good planning and design of the operation can ensure optimal alignment with the marine ecology of the North Sea. The odd 25,000 towers and submerged stone structures adds welcoming artificial reefs onto which all kinds of underwater plants and animals can attach themselves. Using state-of-the-art pile-driving technologies

or gravity-based solutions can largely mitigate negative effects of the construction process, ensuring that sea mammal navigation remains undisturbed. Combining the construction of wind farms with the establishment of fishery-free zones and marine reserves forms a promising synergy.

Last but not least, spatial planning is taking bird migration routes into account when selecting wind farm locations. The zone closest to the coast, which birds use for orientation, should be left untouched where possible. In addition, farms can be temporarily taken out of operation if the radar detects a flock of migratory birds approaching.

A positive effect of this careful planning is that the view from the coast for tourists is not affected. Placed outside the twelve miles zone, the curvature of the earth reduces the visibility on a clear day to a white haze at the horizon produced by the tops of the turbine blades.

Positive Impact on Employment

Even taking into account the high population density, procedural hurdles and compensating for NIMBY (Not In My Back Yard) type setbacks, it should be possible to accomplish the remaining renewable objective of 1,400 TWh with a patchwork of large and small, centralised and decentralised initiatives in these six countries. Projects with the potential to produce the rest of the renewable energy, heat and fuel from solar, water, wind, geothermal, biomass and tidal sources.

Numbers like these remain abstract until one realizes that this means that by 2050 we will need to have installed some 25,000 wind turbines of an average capacity of 10 MW that will have a net coverage of some 57,000 km². This is an average of installing 15 turbines a week. It is clear that we need to start thinking on a different scale. A huge undertaking that demands the

utmost in terms of planning, funding, design and implementation.

This grand operation offers major opportunities for the European economy. All the manufacturing and building of specialized vessels will dramatically increase demand on existing port facilities around the North Sea and may even necessitate port expansions. In this cooperative model, the wind energy system

in the North Sea will quickly move to a tipping point where regional cooperation boosts the efficiency by changing from linear interconnections to a meshed grid.

The positive impact on employment is significant. At all levels and stages of the supply chain there will be jobs for workers of all skills: blue growth for the economy. Above all, the 310,000 jobs are expected to be generated by this North Sea energy harvesting, even outnumbering the 280,000 jobs that will be lost in the offshore fossil fuel industry.

Support from Intense Collaboration

When we wake up, will this scenario survive the pressure of the day-to-day policy dilemmas? We have good reasons to think it can. The interactive production of this installation, in the cultural domain, forged a coalition of key actors. It is the result of intense collaboration between designers and scientists, and a consortium with expert input from builders, offshore specialists, ministries, energy firms, a transmission system operator, port authorities and nature NGOs. It can be done but only when a tailwind can be organized in the shape of realistic pricing or taxation of carbon dioxide that would provide the invisible hand of the market with green gloves. An energetic society needs an entrepreneurial state guided by an unwavering political course.

This imaginary of the North Sea as foundation of a green Next Economy can very well become a reality. Regional cooperation allows us to harvest green energy on a massive scale and can be aligned with actual ecosystem improvement. We have now overcome the crisis of the imagination.

The North Sea, which has been so prominent in our history, will become a pivot in the deep de-carbonisation of our society and a source of prosperity for all. **LAF**

- 11. 风电场的选址充分考虑了鸟类的迁徙路线。
  - 12. 在海上风能单一影响下的沿海地区就业情况：尽管石油天然气产业衰落，但仍然有成千上万的新岗位诞生。
  - 13. 2016年荷兰鹿特丹国际建筑双年展中的装置作品
  - 14. 欧盟成员国的28名能源部长观看项目展示动画
- 11. Bird migration routes are taken into account when selecting wind farm locations.
  - 12. Offshore employment impacted by offshore wind alone: thousands of new jobs despite the decline of the oil and gas industry.
  - 13. Installation IABR 2016
  - 14. The 28 Energy Ministers of the EU member countries watching the animation.