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安徽工程大学
AnhuiPolytechnicUniversity

硕士学位论文

题目 《能源与二氧化碳》(第十一章)
英汉翻译实践报告

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A Report on the E-C Translation Practice of *Energy Versus Carbon Dioxide* (Chapter 11)

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A Report on the E-C Translation Practice of *Energy Versus Carbon Dioxide* (Chapter 11)

Hu Furong

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School of Foreign Studies

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II

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face difficulties with courage, and their belief in my abilities has been a significant driving force for me to persevere and achieve my goals.

All in all, I will value all their contributions as precious treasures in my life and strive to progress in my future career.

摘要

随着人类社会的快速发展，能源的地位和作用愈发凸显，不仅关乎环境保护，还对经济发展和国家安全起到关键的支撑作用。施普林格出版社出版的《能源与二氧化碳》一书即是对这一主题的深入探讨。

本书作者康奈尔.斯坦(Cornel Stan)通过 59 个专题、18 个章节深入探讨了能源与二氧化碳之间的关系，介绍了全球各地的能源现状并分析了未来的能源趋势。本次翻译实践聚焦于该书的第 11 章，主要介绍了光伏、风能和水能这三种可再生能源。本次翻译实践在促进全球可再生能源知识传播、技术交流、政策协同、经济发展以及环境保护等方面具有重要意义。

该章节技术词或半技术词较多；复杂句子多；句子结构严谨；衔接手段丰富、连贯性强。根据莱斯的文本类型理论划分，本书属于信息类文本——注重内容，主要功能是传递信息。因此译者在翻译过程中，要忠实准确地传达原文信息，同时要尽可能确保译文的流畅性、可读性及专业性。此次翻译的重难点在于：一是科技英语技术词或半技术词词义确定。对于技术词，可通过参考平行文本或请教专业人员来确定技术词词义；对于半技术词，可采用结合其联立关系、语法功能或专业领域来推定。二是名词化结构的翻译。可以通过分析其逻辑关系，将其中一些采用主谓结构或者动宾结构来翻译。对于动名词加名词构成的名词性短语，其动名词可以翻译成定语。三是复杂句子的翻译。可采用包孕法、倒置法、拆译法等技巧来准确传达原文的含义。

四是实现译文的衔接与连贯。根据英汉篇章结构的相似性，尽量保留源语文本的衔接和连贯。同时，考虑到英汉语言和思维习惯的差异，适当调整句子结构或通过增删等手段使译文更加通顺流畅。

本次翻译实践让笔者深刻体会到：在翻译能源领域相关文本时，译者需具备扎实的能源、化学、物理等相关学科的专业知识。此外，译者还应熟练运用有效的翻译技巧，以确保译本语言的流畅性和专业性。通过此次翻译实践，笔者不仅较深入地了解了专业翻译的特点和要求，积累了一些经验，还提升了科技翻译的能力，为今后职业生涯奠定了良好基础。

关键词：《能源与二氧化碳》；可再生能源；（半）技术词；名词化结构；长难句；衔接与连贯

Abstract

As human society develops rapidly, the role of energy goes beyond environmental protection. It also supports economic development and national security. The book *Energy Versus Carbon Dioxide*, published by Springer Verlag, provides an in-depth exploration of the increasingly prominent role of energy in society.

The author Cornel Stan explores the relationship between energy and carbon dioxide in this book, covering 59 topics across 18 chapters. The book introduces the current global energy situation and analyses future energy trends. The translation practice focuses on Chapter 11 of the book, which mainly introduces three renewable energy sources: photovoltaics, wind energy and hydropower. Translating the text is of great significance in promoting the dissemination of global renewable energy knowledge, technical exchanges, policy coordination, economic development, and environmental protection.

This chapter contains a large number of technical and semi-technical terms, as well as numerous complex sentences. The sentence structure is rigorous, rich in cohesive devices are and coherent. According to Katharina Reiss's text type theory, the source text belongs to the category of informative texts, which focuses on content and primarily serve the function of transmitting information. Therefore, during the translation

process, the translator should accurately convey the original information while ensuring fluency, readability, and professionalism. During the translation process, three main difficulties arise. Firstly, determining the lexical meanings of technical words can be challenging. This requires referring to parallel texts in related fields or consulting the professionals. Secondly, translating nominalized structures is another difficult issue. Usually, translators should analyze the logic relationship firstly and then translate some of them into verb-object structure or subject-predicate structure. However, for the nominalization of the gerund plus noun phrase, the gerund can be translated as attributive. Thirdly, translating long and difficult sentences can also be a challenge. Techniques such as embedding, reversing, and splitting translations were used to accurately convey the meaning of the original text. Finally, to achieve textual cohesion and coherence in the translated version, the similarities between English and Chinese in expressions and thinking habits are preserved as much as possible. On the other hand, for the differences in expressions and thinking habits between English and Chinese, the sentence structure is to be adjusted accordingly, together with appropriate addition and omission, so that the translation is made more fluent.

In summary, translating popular science texts related to the field of energy requires the translator to have a solid technical knowledge of energy, chemistry, physics and other related disciplines, as well as some theoretical

knowledge of natural sciences. Additionally, translators should be skilled in using effective translation techniques to ensure the fluency and professionalism of the translated text. Through this translation practice, the translator has gained a deeper understanding of the characteristics and requirements of professional translation. Furthermore, she has accumulated some experience and skills in scientific and technical translation, which lays a good foundation for her future career.

Key Words: *Energy Versus Carbon Dioxide*; renewable energy; (semi-) technical words; nominalized structures; long and difficult sentence; cohesion and coherence

Contents

Chapter 1 Task Description

This chapter offers a comprehensive survey of the translation report, which is composed of two parts: an overview of the source of the task and the significance of the translation.

1.1 Source of the Task

Energy is the foundation and driving force for the progress of human civilization. It is crucial to the economy, to people's lives, to national security, and to the survival and development of humanity. It is of vital importance in advancing social and economic development and public welfare. As a result, translating the texts related to energy has a profound impact on national development, world energy development and human destiny.

The book *Energy Versus Carbon Dioxide* was published in 2021 by Springers. The author mainly discussed the relationship between energy and carbon dioxide, introduced the current energy situation and analyzed the future energy forms for effective energy solutions.

The book has not yet been officially published in Chinese and the first three sections of the third chapter are selected as the source text and the translated Chinese versions are 12,856 words. The selected text introduces the three renewable energies——photovoltaics, wind power and hydro power. The vocabulary, sentence pattern and text structure all have the unique characteristics of scientific texts. Meanwhile, it involves several fields such as energy, physics, chemistry, electrical and electronic technology. Therefore, it is a difficult task for the translator who doesn't have relevant professional knowledge.

1.2 Significance of the Translation

First of all, for the translator, this translation practice is a precious opportunity for her personal learning and growth. Through in-depth study of a large amount of related literature, the translator can systematically master the professional knowledge and terminology in the field of energy, which helps to enrich the personal knowledge reserve. At the same time, continuous practice in the practical process enables the translator to be familiar with more translation strategies and methods, which further improves her translation competence in the field of science and technology and lays a solid foundation for her future translation work.

Moreover, this translation practice is also of great significance for practitioners in the field of energy. By reading the translated text, they can quickly grasp the latest developments and trends of energy at home and abroad, so as to deepen their understanding of the clean, low-carbon, safe and efficient energy system. This will not only help them make more informed decisions in their practical work, but also promote the progress and development of the entire energy industry.

Last but not least, this translation exercise will also have a far-reaching impact for the ordinary readers. By reading the translated text, they will be able to better understand the current serious situation of the global energy problem and increase their awareness and sense of responsibility to protect the environment. This not only contributes to the sustainable development of society, but also to the building of a community of shared destiny.

In conclusion, the translation practice not only provides valuable learning opportunities for the translator, but also brings deep understanding and inspiration to practitioners and readers in the field of energy. Joint efforts are entailed to make greater contributions to addressing global energy issues and promoting sustainable development.

Chapter 2 Pre-translation Preparations

To conduct an accurate and professional translation, the translator has made various preparations. These pre-translation measures can help the translator grasp the meaning of the original text quickly, so as to complete the translation work efficiently and accurately. These measures include the features analysis of the source text, the selection of translation tools and the glossary building.

2.1 Features Analysis of the Source Text

The part selected for this translation practice is Chapter 3 in the book. In this part, the author introduced in detail the three main renewable energies: photovoltaics, wind and hydropower. The characteristics of the original text are prominent at the vocabulary level, the syntax level and the language style. A clear comprehension of the characteristics is needed before selecting the corresponding style in the process of translation and presenting an accurate, fluent and decent translation.

At the lexical level, the wording of the source text shows a high degree of professionalism. On the one hand, the source text covers vocabulary specialized in a number of fields, including energy, physics and chemistry. This includes technical terms like “oscillation”, “calorific value”, and “photovoltaic panels”, as well as semi-technical words like “consumer” and “power”. The appropriate use of specialized terms accurately describes the concepts and phenomena in the relevant fields. On the other hand, the frequent use of nominalization in the original text not only increases the professionalism of the text, but also makes the sentence structure more compact and objective. To be more precise, abstract nouns are mainly used to express actions and states, which is one of the main differences between English and Chinese expressions. (李丙午，燕静敏, 2002: 5) The phrases used in the source text, such as “the utilization of energy”, “the expansion of wind energy”, “the activation of various regions”, and “the expansion of wind energy” demonstrate the author’s professionalism and ability to express precisely. In summary, when translating technical words, it is important to use

the appropriate terminology in the target language to ensure accuracy. For semi-technical terms, it is necessary to understand the context and choose appropriate translations. When translating nominalized structures, it is essential to maintain the integrity of their structure and meaning.

Syntactically, the original text is complex due to lengthy sentences, elliptical sentences, cleft sentences, and compound sentences containing multiple clauses. These structures make the text difficult to read and require translators to equip with strong linguistic skills and logical analysis abilities. In addition, to emphasize objectivity and rigor of reasoning, the original text frequently employs the passive voice. In scientific and technical English, the main focus is on describing a process rather than the person performing it. Therefore, the emphasis is on “what to do” and “how to do it”, making the performer of the action irrelevant. This is why the passive voice is commonly used. (韩琴, 2007: 5) Simultaneously, considering the popular science nature of the original text, the translator must possess knowledge of the relevant fields to accurately comprehend and convey the scientific concepts and technical principles. This ensures the translation is both faithful to the original text and easily understood by readers.

In terms of language style, the author’s expressions are in line with the characteristics of popular science papers - objective, concise and easy to understand. For example, the author uses lots of examples from life to explain the principles of energy generation. Some parts are accompanied by field pictures of power stations and structural diagrams of power generation systems as well as data charts, so that readers can be clear at a glance. To produce objective, concise, and comprehensible translations, translators must remain faithful to the scientific nature of the source text, avoiding subjective bias. They should employ simple sentences, utilize common vocabulary, maintain original examples and analogies, and annotate pictures and diagrams accurately, ensuring clear and accurate information transmission.

2.2 Parallel Text Collection

To guarantee accuracy and professionalism in the translation, the translator faced

difficulties finding explanations for certain terms in dictionaries. Therefore, she extensively studied parallel texts related to environmental protection and energy issues, such as the United Nations Sustainable Development Goals, the Action Plan for Peak Carbon Dioxide by 2030, government work reports of 2020, 2021 and 2022 on low carbon and environmental protection. Additionally, to maintain the style and linguistic characteristics of the popular science text, the translator referred to popular science books related to energy, including Intelligent Energy - Our 10,000 Years, which won first prize in the popular science category of the Chinese Society of Electrical Engineering, and New Energy Revolution, which explores the interaction between the new energy revolution and the third industrial revolution.

The translator gained a comprehensive understanding of the energy revolution and future energy forms by referring to these parallel texts. Valuable theoretical and practical knowledge was obtained, which greatly supported the translation work.

2.3 Glossary Building

As the source text includes terms from various fields such as physics, chemistry, biology, and energy, it is essential to establish a glossary before the translation practice, ensuring consistency and accuracy in translation and enhancing the efficiency and quality. Strict management of terminology throughout the project can prevent confusion in subsequent projects. (王华树，张政, 2014: 64) For this popular science article with a wide readership not only practitioners, the translator extracted seemingly simple terms from the original text. The meanings of these terms were determined by consulting dictionaries, parallel texts, and industry websites. For terms with unclear semantics, she repeatedly consulted with the supervisor, graduate students majoring in chemical physics and the technical team during the internship to ensure the accuracy and professionalism.

Through the above steps, the translator finally clarified the meaning of each technical or semi-technical word. The glossary of terms is included in Appendix A.

2.4 Selection of Translation Tools

The translator used Computer Assisted Translation (CAT) tool such as SDL Trados to manage, organize and perform translation tasks more efficiently. It not only creates and stores previously translated passages, but also provides valuable reference and reuses resources for future translation tasks. At the same time, the translator also made use of online dictionaries as well as energy industry websites, such as Merriam-Webster, TermOnline, BJX and Solarbe, to accurately locate and confirm words, phrases and industry terminology. In addition, translation softwares such as Google Translate and DeepL were utilized in order to obtain preliminary translation quickly. These tools mentioned above can be used in flexibly combination during the translation process, which not only improves translation efficiency, but also ensures terminology consistency and overall translation quality.

Chapter 3 Case Analysis

Scientific and technical translation is not merely converting one text into another. Instead, it involves the objective, normative, and accurate translation of concepts, techniques, methods, and conclusions expressed in the original text. This makes the translation of scientific and technological texts challenging for translators. The challenges during the translation process, including determining the lexical meaning of technical and semi-technical words, translating long and difficult sentences, and reproducing the text structure are summarized below. In this regard, solutions are proposed on the basis of practice with typical cases.

3.1 Locating the Meanings of Special Terms

The source text is a scientific and technical document in the field of energy, encompassing various areas such as physics, chemistry, electricity, and thermodynamics. Therefore, the translator must possess a wealth of accumulated expertise to accurately translate the special terms. These terms mainly consist of technical and semi-technical words.

3.1.1 For the Technical Terms

Technical words are unique to a particular discipline and have narrow meanings, while semi-technical words are general vocabularies that appear across disciplines and have important rhetorical and ideological roles. Technical words are highly specialized, with a unique meaning within a specific domain. For instance, technical terms like Cloud Computing (云计算), Internet of Things (IoT) (物联网), and Smart Grid (智慧电网) have precise meanings in computer science and electricity. To determine the meanings, the translator referred to parallel text, consulted experts and specialized dictionaries. As consulting dictionaries is not a difficult task, the translator will not provide further elaboration. Instead, the first two methods will be introduced in detail

through case studies.

3.1.1.1 Referring to Parallel Texts

Parallel texts are reference materials in the translated language that are similar or comparable in content to the original text. They can be different texts on the same subject or field, or translations of the same text by different authors or editions. The use of parallel texts in translation practice is becoming increasingly common due to their significant similarities with the original texts in several aspects. By exploring the linguistic features of parallel texts in depth and analyzing them carefully in comparison with the original texts, translators can accurately reproduce these features in the translation process. This process improves the accuracy and authenticity of the translation and makes it more in line with the reading habits of the target readers, resulting in a natural and smooth translation effect. Therefore, the study and use of parallel texts is significant in translation practice.

Example 1:

ST	TT
A decade later, aerodynamic **blade profiles** were developed in Denmark, which greatly reduced the number of rotor blades.	十年后，基于空气动力学理论，丹麦研发出的**叶型**，极大地减少了转子叶片的数量。

In translating “blade profiles”, the translator first consulted dictionaries and discovered multiple interpretations such as “叶片轮廓”, “叶片剖面” and “叶型”. Although these translations may seem similar at first glance, the translator consulted parallel texts in relevant fields to ensure accuracy and standardization of technical vocabulary. Specifically, the translator referred to the paper titled “Effect of Radial Distribution of Blade Mounting Angle BB(R) on the Aerodynamic Performance of Centrifugal Fan” published in the second issue of 2022 of the “Energy Research and

Information" journal, which enjoys a certain level of authority in the field of energy engineering. In the abstract of the paper, the author explicitly used "blade profile" to refer to "叶型". To further validate this translation, the translator consulted multiple papers on aerodynamic blade design on CNKI. In these papers, "blade profile" in the titles was consistently translated as "叶型", further supporting the judgment that "blade profile" should be translated as "叶型". Additionally, to avoid any confusion, the translator paid particular attention to the usage of "叶片轮廓" and found that it is commonly used to describe the contours of plant leaves. Therefore, based on the above analysis, the translator ultimately determined that "blade profile" should be translated as "叶型" to ensure the accuracy and standardization of the translation.

3.1.1.2 Consulting Professionals

Due to the high level of expertise in the original text, the translator frequently consulted with experts and incorporated their suggestions during the translation process. Through in-depth discussions, she clarified the specific professional domain covered by the original text. Additionally, the experts recommended relevant books to the translator and provided insightful advice on the translation. In the following part, the translator will explain how she sought expert advice for professional terms to ensure the accuracy of meanings and enhance the quality and professionalism of the translation.

Example 2:

ST	TT
Silicium is available everywhere. **Silicium with two oxygen atoms** forms the billions and billions of grains of sand in the deserts and beaches of the earth.	**硅化物**随处可见。地球沙漠和海滩上数以亿计的沙粒中都含有**二氧化硅**。

During the translation process of the term "silicium" , the translator initially rendered it as "硅" based on personal understanding and the interpretation in dictionaries. However, during the subsequent review stage, she consulted with the

Professor Jin Chengxing, who has a solid foundation in science and technology and conducted the sci-tech English translation in various fields for above 30 years. He provided insightful opinions on the translation of “silicium”: in the absence of contextual cues, “silicium” can be translated as “硅”. However, since the subsequent text refers to “silicon dioxide” as “Silicium with two oxygen atoms”, it is necessary to reconsider the translation of “silicium” in the preceding context. It may be more appropriate to translate it as “硅化物” since there is a significant difference between silicium and silicon from a professional perspective. Siliciums are compounds formed by the combination of silicon with other elements, while silicon itself is an element. Therefore, when translating “silicium” as “硅化物”, rendering the relevant sentence as “硅化物随处可见” would be more precise and reasonable.

3.1.2 For the Semi-technical Terms

The situation is different for semi-technical words. These words usually fall somewhere between technical terms and ordinary vocabulary, and their meanings may vary depending on the context. Therefore, to comprehend and use semi-technical terms, and the following three methods, apart from referring to parallel texts or consulting the professionals, are applicable to the treatment of semi-technical terms.

3.1.2.1 In Light of Specific Domain

Scientific and technological texts are typically not limited by local or foreign cultures, unlike other types of texts. Therefore, during the translation process, its vocabulary can usually be accurately translated into the target language. Additionally, the words often have multiple meanings and uses. When applying the same word or phrase to a new field, it may acquire a new meaning and have a professional interpretation. Therefore, during the translation process, it is crucial for the translator to possess interdisciplinary knowledge and stylistic awareness. Each word needs to be carefully identified to ensure the translator understands its precise meaning and selects the appropriate translation.

Example 3:

ST	TT
The **hub** height of this wind turbine can be between 101 and 161 meters.	这种风力涡轮机的**轮毂**高度在 101 到 161 米之间。

Most English learners commonly perceive the word “hub” to mean “center”, referring to an important center for an activity. Also, it has another common meaning, which is “交通枢纽”. However, the word’s meaning changes when used in specific areas, such as energy and power. According to the context, the term “hub” refers to the coupling part that holds the blades to the rotating shaft. Therefore, it would be more accurate to translate it as “轮毂”. When analyzing the source text, the translator should pay attention to the specific meaning of a certain expression in a specific context, rather than just seeing its literal meaning. (蔡力坚, 2021: 188) This highlights the importance of context in accurately understanding the meaning of words. Therefore, it is crucial to determine the precise meaning of words based on specific domain, rather than relying solely on their general meaning.

Example 4:

ST	TT
Using short power **grids**, they can efficiently supply the mostly existing **grids** in neighboring cities with electrical energy in an electricity mix, regardless of fluctuation throughout the day and depending on the weather.	在混合式供电网络中，利用短途**电网**，可以有效地为邻近城市的现有**电网**供电，全时段稳定，不受天气影响。

In professional contexts, the term “grid” refers to a vast network that carries electric power, rather than the grid of neatly drawn lines commonly referred to daily discourse and written text. Given the present context, it is evident that the term “grid”

ought to be rendered as “电网” in translation. This terminology refers to the fundamental infrastructure facilitating the transmission and distribution of power, constituting a vital energy network integral to contemporary society.

3.1.2.2 In Light of Collocation

Lexical collocation refers to the collocation of words. Words collocation occur within sentence elements, such as the collocation of the central word (noun) with its modifier (determiner) within noun phrases; the collocation of verbs with their objects or gerunds within verb phrases, and so on.

In Scientific and technical English texts, words have multiple meanings, which can vary depending on their collocations. Understanding these collocations can help narrow down the meaning of a word. The translator has found that using word association to determine the meaning of semi-technical words is effective in improving the quality of translations.

Example 5:

ST	TT
Of course, you can compress the hydrogen at 600-900 bar, or cool it to minus 253 °C, as in **fuel cell** systems for automobiles.	当然，你可以把氢气压缩至600-900巴，或者像汽车**燃料电池**系统那样，将其冷却到零下253摄氏度。

In this case, the word “cell” has several common meanings, such as “蜂窝”, “细胞”, “小隔间” and “电池”. However, when “cell” is used in conjunction with the word “fuel”, only the meaning “battery” is appropriate. This is because in the context of automobiles and battery systems, “cell” usually refers to the basic unit that makes up a battery, which is used to store and provide electrical energy. Therefore, “fuel cell” can be translated as “燃料电池”.

Example 6:

ST	TT
The current can be tapped using appropriate contacts at the top and bottom. The contacts are connected to a **consumer** via **cables**. Such a consumer can be a light bulb or contact an electric motor.	通过顶部和底部适当的触点分接电流。触点再通过**电缆**连接到**用电设备**——可以是一只灯泡也可以是一台电动机。

The word “consumer” is usually delivered as “a person who acquires goods and services for his or her own personal needs”. If the contacts are connected to a person via cables, it must be against humanity. Therefore, “consumer” can’t be translated as “消费者”. The combination of “consumer” and “cable” and the following sentence “Such a consumer can be a light bulb or contact an electric motor” suggests that “consumer” can be translated as “用电设备”.

Therefore, when translating, the translator should not only consider whether the translation is logical, but also check the translation carefully in order to achieve professionalism.

Example 7:

ST	TT
An **instantaneous power** in a **wind power plant** is nothing else than the flow of kinetic energy that the wind brings with it.	**风电场**的**瞬时功率**就是风带来的动能流。

“power” in this sentence has multiple meanings, which is a common occurrence in scientific and technical English texts. The first “power” is associated with “instantaneous”, meaning “瞬时的”. It is important to choose precise word to avoid

confusion. Therefore, the word “power” should not be translated inaccurately as “能力”, “权力”, or “电力”. The term “power” in this context refers to the rate at which electrical energy is fed into or taken from a device or system, which can be translated as “功率”. The phrase “instantaneous power” can be translated as “瞬时功率”. The second “power”, which is collocated with “plant”, refers to electricity generation. In this context, the word “plant” refers to a factory or a station. Therefore, the phrase “wind power plant” can be translated as “风电场”.

3.1.2.3 In Light of Grammar Function

In addition to associative relations of words, it is also necessary to infer the meaning of words in combination with the context and grammatical relations. In scientific and technical English translation, it is common to determine the meaning of words based on their grammatical functions, as this is a scientific and logical method that involves two aspects: one is to determine the meaning of words on their part of speech within the sentence, the other is to determine the meaning of words on the sentence structure. The translator focuses on the former method in determining meaning, as the latter one is not extensively covered in the original text.

Example 8:

ST	TT
In the USA, onshore wind turbines reach 2600 - 3500 full **load** hours, which corresponds to a utilization rate of 30 - 40%.	美国陆上风力涡轮机的满**载**小时数达到 2600 – 3500，相当于 30 – 40%的利用率。

During the analysis of this sentence, the translator discovered that although “load” is typically used as a verb, meaning “to put something into it so that it is ready to use”, but in this sentence, it is not being used as a verb. As “full” is an adjective, it is well known that adjectives are usually used to modify nouns or linking verbs, not to directly

predicate verbs. Therefore, it is reasonable to assume that “load” is being used as a noun in this context. Considering the context, it can be inferred that the phrase “full load hours” is a proper noun in the field of electricity, referring to the time when equipment is running at full load. Therefore, it is appropriate to translate it as “满负荷小时数”.

Above all, the methods mentioned above for the meaning determination of the technical or semi-technical words can be effectively used separately and sometimes employed in a combined way for verification.

3.2 Translating Nominalized Structures

The extensive use of nominalization structures is a prominent characteristic that sets English for Science and Technology (EST) apart from General English, making it an independent discipline. (裴邦贵, 1987: 27) Nominalization is a grammatical phenomenon that converts verbs, adjectives, and other parts of speech into noun forms. It is a common word-formation technique in English grammar. EST primarily employs this structure to achieve objectivity, precision, and information density, as well as to enhance expression efficiency and construct a clear logical framework. Nominalization structures play an irreplaceable role in EST, facilitating the accurate communication of scientific and technological information and promoting exchanges and knowledge dissemination in the field of science and technology.

In this translation practice, there are two main categories of nominalization structures: 1) Compound nominalization structures, which consist of a central noun and multiple modifiers such as adjectives, nouns, adverbs, participles, and prepositional phrases; 2) Gerunds and their phrases, which use verbs with the “-ing” suffix to represent actions, processes, results, products, or things related to a certain action or concept. (金成星， 胡国政, 2002: 66) In the translation process, the translator mainly adopts two methods to ensure the accuracy and fluency of the target texts:1) translating nominalization structures into verb-object or subject-predicate structures; 2) translating them into attributes.

3.2.1 Translating into Verb-object Structure or Subject-predicate Structure

English tends to be static, which is mainly reflected in its extensive use of nouns. In contrast, Chinese tends to be more dynamic, relying mainly on the use of verbs. Given the significant linguistic difference between English and Chinese, it is crucial to consider the treatment of nominalized structures during the translation process. One approach is to transform the noun into a verb and then analyze the logical relationship between the noun and subsequent words. If there is a verb-object relationship with the following words, it should be converted into a verb-object structure. If it forms a subject-predicate relationship, it should be converted into a subject-predicate structure. Through the conversion, the translation will be more in line with Chinese expression habits and more fluent.

Example 9：

ST	TT
It is indisputable that people on earth absolutely need emission-free photovoltaic energy. However, this is not a universal solution, but **a good addition to a reasonable energy mix.**	无可争议，人类十分需要无排放的光伏能源。虽然，这个解决方案并非万能的，但是**添加光伏能源较合理地（完善了）混合式能源结构。**

This example demonstrates a common compound nominalization structure, consisting of an adjective, a noun, a preposition, another adjective, and a noun phrase. When translating, the translator recognized that “addition” comes from the verb “add” plus the suffix, and therefore decided to restore its verb morpheme, translated as “添加”. She then analyzed the logical relationship and found that “a universal solution” (i.e. photovoltaic energy) serves as the object of “add”. Moreover, the “conversion” technique was employed to transform the adjectives “good” and “reasonable” into

'adverb'. This adjustment aligns the translation with Chinese expression habits. To summarize, the underlined section is accurately and fluently translated as “添加光伏能源较合理地（完善了）混合式能源结构”. “添加光伏能源” is a verb-object structure in Chinese, fully reflecting the meaning of the original text.

Example 10：

ST	TT
Due to **the better cooling of the cells**, this system has a higher efficiency than that on the ground.	由于水面上**电池冷却效果更好**，该系统的在水面上的效率高于在地面上。

The nominalized structure here is “adjective + gerund + preposition + noun”. The gerund “cooling” is formed by adding “-ing” to the verb “cool”. The translator analyzed the logical relationship and initially considered whether it was a verb-object or subject-predicate relationship, because in Chinese colloquial expression, “电池冷却”and “冷却电池” have similar meanings. But after careful analysis, it is found that there is no indication of what caused the cell to cool. Therefore, it would be more appropriate to treat it as a “subject-predicate structure”. Given the common use of category words in Chinese, the translator added the word“效果” based on the context, which would clarify the semantic meaning. Therefore, the entire nominalized structure can be rendered as“电池冷却效果更好”.

3.2.2 Translating into Attributives

The use of gerunds and their phrases in nominalized structures is a unique phenomenon in scientific and technical English. They serve three main purposes: forming technical terms, describing the process of action, and combining gerunds and nouns to form noun phrases. The final case, in particular, is common in this translation practice. Consequently, this report will provide an in-depth discussion of this case with

specific examples. In the third structure—gerund + noun, the grammatical function of gerunds here is similar to that of adjectives, which are used to modify, qualify, and describe the qualities and characteristics of nouns. Therefore, it is typically translated as an attributive to ensure the accuracy and fluency of the target language.

Example 11：

ST	TT
The third source of vibration is the mast itself, which carries the heavy **rotating wings** at a height of 161 meters.	振动的第三个来源是风电塔本身，它承载着 161 米高且很重的**旋转叶片。**

In this example, “rotating” is formed by the verb “rotate” and the suffix “-ing”, which clearly conveys that the wings are in motion. The words “heavy” and “rotating” function as adjectives, modifying “wings” and emphasizing the weight and motion of the wings. Translating 'rotating' as an attributive “旋转的”not only preserves the original meaning but also conforms to Chinese expression habits, allowing readers to intuitively understand the state of the wings.

Example 12:

ST	TT
Nothing against it if wind turbines or wind farms are located on desolate fields, or in former open cut **mining** fields.	如果风力涡轮机或风力发电场位于荒凉的田野上，或位于此前露天的**矿区**里，这无可厚非。

The underlined phrase is formed by combining the gerund of the verb “mine” with “fields”, which refers to an area dedicated to mining. This expression clearly reveals the specific use of the place, i.e. as a site for the extraction of mineral resources. In the

translation process, it is important to accurately convey the meaning of the phrase while also ensuring simplicity. While “开采场地” can convey the basic meaning of “mining fields”, it is obviously acceptable. To achieve simplicity and conciseness in the translation, we can further condense it into “矿区”. Such version not only preserves the original meaning but also conforms to Chinese expression habits, resulting in a more fluent and natural translation.

3.3 Translating Long and Difficult Sentences

The main features of the popular science documents are the complexity of compound sentence types, long sentences, passive voice, technical terms and interjections and appositives. Susan Bassnett (2010) believes that sentence structure can be extended and combined with various means of connection to form long and complex sentences. (Susan Bassnett, 2010) These can enhance the rigor and comprehensiveness of scientific concepts and reasoning processes, making sentences intricate and complex, causing confusion for readers and hindering their understanding of the intended meaning. Therefore, for translators, the translation of long sentences in scientific and technological English is increasingly important. To ensure better comprehension, readers should possess a certain level of English reading and analytical capacity. Additionally, producing an accurate and fluent translation requires the use of appropriate translation techniques.

Correctly analyzing and understanding sentence structure is a prerequisite for translating lengthy sentences. By analyzing the grammatical structure of a sentence, one can identify the main clause, subordinate clause, participial phrase, and so on. According to the main-subordinate relationship, the core meaning of the sentence and the meaning of each level can be identified and the logical relationship between them can be sorted out. Translation is then carried out in line with Chinese expressions. (于建平, 2000: 14)

For long and complex sentences, the translator follows these three steps: Firstly, it is necessary to determine the meanings of technical words in long and complex

sentences. For example, if the meaning involves power generation, relevant information should be consulted to understand the principle. Secondly, the syntactic structure of long and complex sentences should be analyzed, along with the logical relationship between clauses and between clauses and the main sentence. Finally, the translation process should take into account the differences between Chinese and English languages, contexts, and expression habits. Three main translation techniques mainly used in translating will be illustrated in this report: (1) embedding, (2) reversing, and (3) splitting.

3.3.1 Embedding

The technique of embedding, also known as prepositioning, is used to render a verb or noun phrase in an English sentence into a Chinese verb or noun phrase.

As Chinese word order is primarily based on the preposition of modifiers, it is preferable to use embedding when translating into Chinese. This makes the sentence more concise and strengthens the overall structure. This method is suitable for translating restrictive definite clauses. Such clauses are closely related to the antecedent word and can usually be translated into Chinese definite phrases or structures using the character "的", following the Chinese definite antecedent custom. These phrases or structures are then placed in front of the antecedent word, allowing the subordinate and main sentences to be combined into a single sentence. (袁瑛, 2010: 6)

Example 13:

ST	TT1	TT2
The reorientation of the energy industry in many countries around the world towards renewable energy sources, **which was caused by these oil**	许多国家的传统能源行业公司开始向可再生能源转型，**这是由石油危机造成的，**大大加快了风力涡轮机的建设。	**石油危机导致**许多国家的传统能源行业公司开始向可再生能源转型，大大加快了风力涡轮机的建设。

crises, has significantly accelerated the construction of wind turbines.		

The stem of the sentence is “The reorientation of the energy industry has significantly accelerated the construction of wind turbines”. The clause “which was caused by these oil crises” is a non-finite qualifier preceded by “which”. The logical relation here is the cause of the main clause. For TT1——the first translated version, if we follow the logical order and translate directly, it is easy to cause ambiguity. This expression does not conform to the habit of Chinese expression. The communicative translation theory is content-focused, so both the content and expression of the translated text need to be understood and accepted by target language readers. (刘树森, 1992: 49) Therefore, the translator made the adjustment again, using the method of embedding, also named determinative preposition: “which was caused by these oil crises” was translated into “石油危机造成”, so that the logical relationship between the translated sentences is more compact, clearer.

3.3.2 Reversing

Reversing is the inversion of sentence elements. Generally, after the English long sentences are merged or cut off into long or short sentences according to the thought group, either partial adjustment or overall adjustment is made, the principle is to make the Chinese translated sentences conform to the customary expression in the arrangement, that is, to the general logical order of modern Chinese rational narration. In Chinese translation, the thought group may be completely or partially reversed according to the specific situation. (王恩科，李昕, 2007: 77) The translator can only achieve the functional equivalence when translation some texts since all the language has the capacity to carry the same meaning but there are many differences lied in every language. Therefore, when translating, translators should pay particular attention to the

difference in the order of thinking between English and Chinese, and use the inversing method appropriately to adjust the order of clusters or phrases so that the translated sentences conform to the general narrative order of modern Chinese.

Example 14:

ST	TT
What comes out of this is initially **fascinating and energy-hungry-calming**, at least virtually: "The sun provides ten thousand times the energy we need. Why don't we use them in clever plants, **is it more convenient** for people to tap into dirty energy sources such as oil, natural gas and coal?"	"太阳提供的能量是我们实际所需的一万倍。我们何不将此运用在智能化工厂中？难道人们利用石油、天然气和煤炭等非清洁能源**会更方便吗？这一结果乍看有趣，至少让高能源消耗问题几乎能得到缓解。**

The translator has used the method of reversing twice in translating the sentence. One instance is in the phrase "fascinating and energy-hungry-calming", which is a summary expression. In English, it is customary to summarize and then elaborate, while in Chinese, the opposite is true. Therefore, the translator adjusted this part to the end of the sentence and added the subject "这一结果" to improve the natural and fluent cohesion of the sentence, taking into account the difference between Chinese and English expression habits and thinking order. The other is in the sentence "is it more convenient...", which contains a compound structure with the verb infinitive. According to the rules of grammar, the real subject of the sentence is "people to tap into dirty energy sources such as oil, natural gas and coal". Therefore, it is recommended to rephrase the sentence to make it clearer and more concise. "is it more convenient" was translated into "更方便吗?" at the end of the sentence.

Example 15:

ST	TT
A second source of pressure waves are the vibrations in each sword (wing) itself, due to the variable pressure load between base and tip, **at the speeds which**, **depending on the speed and position on the wing,** change from 2 to 120 km/h, respectively from 10 to 390 km/h.	压力波的第二个来源是每个叶片本身的振动，由于基座和尖端之间的压力载荷变化导致的。**根据叶片的旋转速度和位置不同，振动速度**分别从 2 到 120 公里/小时，再到 10 到 390 公里/小时不等。

In translating, the present participle “depending on the speed and position on the wing” was repositioned preceding “at the speeds which” due to dual considerations. Firstly, grammatically, “at the speeds which” and “the change from...to 390 km/h” constitute an attributive clause, necessitating the rearrangement. Secondly, Chinese and English differ significantly in terms of thought patterns. Chinese thinking tends towards an inductive approach, deducing the general from the specific, leading to a semantic structure that is lighter at the beginning and heavier at the end. When dealing with complex sentences involving conditions, assumptions, causes, concessions, or analytical reasoning, Chinese typically adopts a sequential and progressive narrative order, proceeding from the earlier to the later, from cause to effect, from assumption to inference, and from fact to conclusion. (程洪珍, 2005: 52) Therefore, the revised translation aligns more closely with Chinese thinking and expression patterns.

3.3.3 Splitting

In translation practice, when faced with complex sentence structures or specific expressions, the traditional cutting method may not be able to smoothly separate a component. In such cases, we need to use a special translation technique called “splitting”. The splitting method refers to the practice of separating certain components

(words, phrases or clauses) from the main stem of a long English sentence to facilitate overall sentence arrangement. (刘宓庆, 1998: 211)

Splitting is an effective translation technique. It involves separating a modifying constituent that carries a lot of information, which may be difficult to integrate directly into the overall meaning of the sentence due to its position or relationship with other constituents. By separating it out, the original text's meaning can be conveyed more effectively, ensuring fluency and smoothness in the translation.

Example 16:

ST	TT1	TT2
The displacement of the air **with the three long swords at 200-300 km/h** provokes not only noise **from lateral friction with the air** but also pressure waves due to **the frontal contact of the wing edges with the air in front of it**.	三个叶片以 200-300 公里的时速使空气发生位移，不仅产生了与空气横向摩擦的噪音，还产生了叶片边缘与前方空气正面接触产生的压力波。	**在 200-300 公里的时速下，风力发电机的三个叶片**使空气发生位移。它们**与空气的侧向摩擦**产生了噪音。此外，**叶片边缘与前方空气的前部接触**，又产生了压力波。

The original text, a lengthy and intricate sentence, necessitated a multifaceted translation process to enhance comprehension and expression. The translator recognized the “not only...but also” structure within the original, indicating dual meanings. Initially, a literal translation was used, yielding the first version with translationese and ambiguous logical connections. Subsequently, modifications were necessary. To enhance clarity and readability, the sentence was divided into three distinct parts: “The displacement of ……provokes”, “noise ……the air”, and “pressure waves …… air in front of it”. This segmentation not only aligned with the preference

for shorter sentences in Chinese but also improved the logical flow, making it more accessible to the target readers.

In summary, the splitting method requires proficient translation skills and experience to ensure both quality and accuracy. It is a crucial skill to master, particularly when translating prolonged and intricate sentences.

Example 17:

ST	TT1	TT2
However, these oscillations have a different frequency **than that of the air pressure waves in front of the wing edges** and **then those of the wings over their length.**	然而，这些振荡的频率与叶片的气压波以及叶片长度方向的气压波的频率不同。	然而，这些振荡的频率不同体现在两方面。**一方面，与叶片边缘前部的空气压力波的频率不同。另一方面，与叶片长度方向的频率不同。**

Initially, the translator adhered to the original sentence order, yet the resulting translation appeared unrefined and unaligned with Chinese idiomatic expression. Upon a thorough analysis of the original sentence's logical relationships, it became evident that the disparities in vibrational frequency were primarily in two distinct aspects. Consequently, to more effectively convey the original sentence's intended meaning, the translator divided it into three components: "However...frequency" for a general overview of vibration frequency, "than that...edges" to clarify the nexus between frequency and edges, and "than those...their length" to further elucidate the correlation between frequency and length. Additionally, the translator incorporated the connecting phrases "一方面" and "另一方面", enhancing the translation's logical clarity and aligning it more closely with Chinese reading conventions, thereby facilitating

comprehension among Chinese readers. The revised translation not only faithfully preserves the original meaning but also expresses it in a more fluent and natural manner.

3.4 Embodying Textual Cohesion and Coherence in the Target Text

Chinese and English are quite different in terms of sentence construction and text structure. Nida believes that perhaps one of the most important linguistic distinctions for English and Chinese, is the contrast between the hypotaxis and parataxis. (Nida, 1982) Chinese emphasizes parataxis, i.e. the expression of sentence meaning and logical relations does not depend on formal means, but is revealed naturally through implicit coherence and narrative order, which makes Chinese sentence structure flexible and variable. English, on the other hand, is more inclined to hypotaxis, and the logical relationship between sentence components is shown directly through explicit linking devices such as connective words. The difference between parataxis and hypotaxis at the sentence level, which is rigorous in sentence structure, further affects the textual structure of Chinese and English. In order to ensure the wholeness and coherence of the text, it is essential to take cohesion and coherence into account when translating.

“Cohesion is the network of surface relations which link words and expressions to other words and expressions in a text, and coherence is the network of conceptual relations which underlie the surface text. Both concern the way stretches language are connected to each other. In the case of cohesion, stretches of language are connected to each other by virtue of lexical and grammatical dependencies. In the case of coherence, they are connected by virtue of conceptual or meaning dependencies as perceived by language users”. (Mona Baker, 2000: 218) Cohesion refers to the use of connecting words such as “and”, “or”, “but”, and “because” to link different parts of a text. It can also be achieved through the use of pronouns, substitutions, omissions, subordinating conjunctions, and word combinations. On the other hand, coherence refers to the contextualization of a text, where the reader is able to understand the text based on their background knowledge of the language. The application of cohesion and coherence

principles will not only help the translator to understand the source text, but also make the translation more accurate and smoother. (顾晓波, 2015: 38)

There are three ways of dealing with textual coherence and articulation in scientific and technical translation: 1) Maintenance of the cohesion and coherence in ST; 2) Rearrangement of the cohesion and coherence in ST; 3) Addition or omission of the cohesion and coherence in ST. The first method is easy to follow and requires no further explanation. Thus, the focus will be put on the latter two methods.

3.4.1 Rearranging the Sentence Order in Target Language

When translating scientific and technical texts, it is recommended that the standards expected by the reader are fully taken into account and that the structure of the source text is retained as far as possible. However, to ensure inter-sentence logical coherence, it may be necessary to rephrase certain sections. Directly maintaining the original expression can result in a "translationese". The main feature of translationese is that it is excessively faithful to the form of the source language and largely neglects the characteristics of the target language, which is mainly due to the inadequate mastery of the target language or the neglect of the differences between two languages at the lexical, syntactic and textual levels. (梁春媚, 2014: 9) Therefore, to ensure fluency and accuracy in translation, the translator must make appropriate arrangement to the coherence of the text based on the logical thinking and expression between English and Chinese. This will better adapt to the expression habits of the target language and meet the reading needs of the audience. It enhances the naturalness and readability of the translated text, enabling readers to better comprehend and accept the information presented in the original text.

Example 18:

ST	TT1	TT2
And **as for the greenhouse**, so also for	**至于温室**，光热系统中的热水模块（太阳能集热	用于加热水的光热系统中，热水器（太阳能集热

the hot water modules (solar collectors) in the photothermal systems for water heating. A glass surface allows sun rays in the wavelength range of light to pass through. However, when the sun's rays have transferred some of their energy, as heat, to the room or plants behind the glass surface, their intensity is weakened and the vibrations of their electromagnetic waves become slower.	器）也是如此。一定波长范围内的太阳光线都可以穿过玻璃表面。然而，当太阳光将其部分能量，如热量， 照到玻璃后面的房间或植物时，光线的强度会减弱，电磁波的振动也会变慢。	器）**和温室的原理一样**。一定波长范围内的太阳光线都可以穿过玻璃表面。然而，当太阳光将其部分能量， 如热量， 照到玻璃后面的房间或植物时，光线的强度会减弱，电磁波的振动也会变慢。

Initially, the translator tried a literal translation but found that it lacked fluency. Specifically, there is a semantic and logical break between the second sentence and the preceding text. Without knowledge of the original text, the reader may become confused when reading the translation directly. At the lexical level, the corresponding components of the two languages can still be found, but the sequential order is not the same, which is often the result of the so-called word order adjustment according to the different language habits of the two languages. As a result, the translator decided to rearrange the sentence components and consider them within the context of the latter. In the second sentence "A glass surface allows sun rays in the wavelength range of light to pass through", the phrase "a glass surface" refers to "greenhouse". To ensure logical

coherence and semantic clarity between sentences, the translator put “And as for the greenhouse” at the end of the first sentence, translating it as “和温室的原理一样”, so as to make a more natural connection with the latter sentence.

Example 19:

ST	TT1	TT2
But at that time, mostly everyone, people like factories, enjoys their night’s rest. From there, “the water is pumped up from the lower to the upper basin, **with the help of electricity from the grid**, **which almost no one needs at the time.** And that’s how it goes day and night.	但在那个时候，大多数人（像工厂的人）都喜欢晚上休息。**在电网供电的帮助下，**水从底部的盆地被泵送到上部盆地，**当时几乎没有人需要电网供电。**这就是它日夜运转的方式。	然而，大多数人（如工厂的人）夜里正在休息，此时**几乎无人需要用电。**随后，**利用电网中的电力，**水泵将水从低处抽送到高处的水库。白天和晚上就这么运作的。

The first version fails to align with the logical structure of Chinese expression. The fundamental difference between English and Chinese languages lies in their respective sentence focal points, with English exhibiting a front-focus tendency and Chinese demonstrating a back-focus pattern. Consequently, two adjustments are necessary to enhance the translation’s quality. Firstly, the phrase “with the help of electricity from the grid” has been relocated to precede “the water...”, resulting in the translation “利用电网中的电力，水泵将水. . . ” Secondly, from a logical perspective, people typically rest during the nighttime with a surplus of electricity in the grid for water pumping. Therefore, the clause “which almost no one needs at the time” has been repositioned to the end of the first sentence. The entire sentence is then translated as “然而，在夜间，

大多数人（如工厂工人）正在休息，此时几乎无人需要用电”.

Hence, it is imperative to acknowledge and accommodate the disparities between Chinese and English when translating. In certain instances, with the help of common sense, the logical connections within sentences can be quickly figured out, as exemplified above. By rearranging and restructuring sentences, as well as clarifying logical connections, the target text will be more comprehensible to target readers.

3.4.2 Adding or Omitting of the Cohesive Words in Source Text

During the process, it may be necessary to add or omit certain words or phrases in order to perfectly convey the meaning and style of the original text and make the target text more expressive. In English-Chinese translation, addition refers to the inclusion of words, sentences, or paragraphs in the translation to accurately convey the content of the original work or achieve a specific translation goal, based on the characteristics of the target language or cultural norms. (熊兵, 2014: 82) To maintain cohesion and coherence in scientific and technical English translation, omission is a common method. House agrees that when translating, follow the principle of simplifying by deleting complexity, reducing words to ensure that the translation aligns with the characteristics of scientific and technological style, such as conciseness, accuracy, and logical rigor. (House, 1977: 103)

Unnecessary modifiers or redundant information in the original text can affect the internal logic and coherence between parts of speech or sentences, and do not need to be fully presented in the target language. Omitting can improve fluency and readability by avoiding length and clutter.

Example 20:

ST	TT
The largest photovoltaic plants in the world have been even built in very sunny regions. In Benban, Egypt, a	世界上最大的光伏电站都建在阳光非常充足的地区。**例如：**在埃及本班，阿斯旺附近的沙漠中建成了一座光伏电

photovoltaic plant with a calculated peak output of 1800 megawatts (MW) was built in the desert near Aswan (earth observatory. nasa, 10/2019). In Abu Dhabi, a plant with 1177 MW is under construction….	站，计算峰值输出功率为 1800 兆瓦（MW）（美国国家航空航天局地球观测站，2019 年 10 月的数据显示）。在阿布扎比，一座 1177 兆瓦的光伏电站正在建设中,…

There are three sentences in this paragraph, with the first serving as the general statement and the subsequent two illustrating the examples of photovoltaic power stations. To embody the coherence and logic in the target text, the translator has inserted "例如" between the first two sentences, serving as the complement to the first sentence and the guide to the specific examples. By adopting the addition method, the connection is clearer. The translated paragraph obviously reads smoother and easier to understand, thus ensuring the acceptability.

Example 21:

ST	TT
The fact that the energy flux density of solar radiation in the Earth's atmosphere itself fluctuates between zero and 1000 watts per square meter has already been mentioned. However, photovoltaic cells are expected to achieve the 1000 watts, i.e. 1 kw of power, on a panel with an area of 1 square meter. Unfortunately, **this** does not work.	上文提到，地球大气层中太阳辐射的能流密度在 0-1000 瓦特/平方米之间波动。然而，人们指望光伏电池能在 1 平方米的面板上实现 1000 瓦的功率，即 1kw 的功率。可惜，行不通。

In general, the demonstrative pronoun "this" is used in a variety of ways. In this case, "this" refers to the aforementioned expectation, namely that photovoltaic cells

would achieve 1 kW of power on a panel with an area of 1 square meter. The logical relationship is self-evident. The difference in the expression habits of Chinese and English leads to different approaches to clarifying logical relationships between sentences or paragraphs. English tends to use articulation or demonstrative pronouns to achieve this, while Chinese emphasizes the meaning and avoids the repeated use of demonstrative pronouns. In this case, the translator adopted the omitted translation method, without translating "this." The method avoids semantic repetition and keeps the semantics clear, so as to keep the translation fluent and concise, and in line with Chinese expression habits.

Overall, when dealing with coherence and cohesion, there is no one-to-one strategy in translating. Translators should be attentive to the underlying logic between sentences and paragraphs and apply translation strategies flexibly based on the specific situation to achieve the best translation effect.

Chapter 4 Summary

During the whole translation process, in order to produce appropriate translation of the special terms in the related fields, the nominalized structures, long and complex sentences while embodying the logic expressions in target language, the translator needs to read a lot of parallel texts and consulted industry experts or the supervisor. To ensure the translation quality, self-examining, peer-reviewing by groupmates and the supervisor's reviewing are entailed and all the feedback are to be valued and embodied in revised versions. This process may repeat several times, which not only enhanced the translators' experience and ability but also established a strong foundation for her future translation work. Certainly, there still exits some limitations, which needs to be resolved through great efforts.

4.1 Quality Control

For the original text is a highly specialized scientific text, it is of the utmost importance to ensure the quality of the translation. Although the translator has made sufficient preparations before translation, post-translation proofreading is a crucial step to deepen understanding and expression, which requires repeated revision before finalizing the translation.

After completing the initial translation, she utilized the Xbench software to finish a basic review of the translation. The review included, but was not limited to, checking and correcting issues such as word consistency, omission of translations, numerical accuracy, repetition of words, matching of key terminology, standardization of capitals and lower case, extra spaces and punctuation, and so on. In the second revision stage, an in-depth self-proofreading of the translation over a period of approximately one week was completed. The process involved focusing on the fidelity of the translation and the fluency of the language. To check the textual coherence, the target text was read through without reference to the original text with marks on any ambiguous or poorly

translated sections. In the third revision, the translator and team members engaged in an in-depth discussion regarding the lexical choice of polysemous words in the original text, the clarity of the internal logic of the target language, and the standardization of Chinese expressions. Additionally, more accurate methods for dealing with ambiguous translations were proposed by teamwork. Given that the book was translated by our team, the language style and terminology of each other's translations were also standardized in order to ensure overall consistency. The next step was to submit the translation to my supervisor for proofreading so as to get his precious advice or suggestions on revision. Finally, the translator conducted the revisions by integrating all his feedback into the last version.

4.2 Gains

The translation of sci-tech documents is really a tough job, which renders me work restlessly until midnight for quite a long time. However, with the help of my peers and supervisor, I managed to walk out of the difficult period and succeeded in completing the translation task, from which valuable experiences were gained.

In determining the meaning of scientific and technological English terms, the translator conducted internships in the energy industry company, participated in industry exhibitions, consulted various professional websites, read parallel texts, built a glossary, consulted experts and discussed with team members, and worked together to revise the translations over and over again. During the process, the translator explored methods for figuring out the meanings of scientific and technical English vocabulary, including lexical associative relations, grammatical functions, and areas of specialization. Additionally, the translator gained knowledge about the energy industry, combining translation with daily work, and gained a deeper understanding of the energy industry and translation.

In translating nominalization, the translator has gained a deep understanding of the fundamental differences between English and Chinese: English tends to use nominalized expressions, exhibiting a static linguistic feature, while Chinese prefers to

use verbs, presenting a dynamic linguistic style. Therefore, during the translation process, the translator first focuses on transforming the nominalized structures in English into verb expressions in Chinese. Then, deciding whether to transform them into subject-predicate or verb-object structures was based on the specific logical relationship. Additionally, she places particular emphasis on a frequently disregarded form of nominalization, namely the combination of gerunds and nouns. To address this issue, the strategy of translating gerunds into Chinese attributes was employed to ensure accuracy and fluency in the translation. Through meticulous analysis and processing, the translator aims to preserve the meaning and style of the original text in the translation, while ensuring that it is natural and authentic.

For the translation of long and difficult sentences, the translator adopts the three translation techniques: reversing, splitting and embedding, and unconsciously integrates these three techniques with other techniques or strategies learnt in the previous translation courses as her translation level improves. Although the individual sentences in the translation read smoothly, the paragraphs appear fragmented due to the translator's lack of understanding of the overall logic and coherence of the text. This translation practice highlights that scientific and technical texts are highly logical, often with invisible connections that are difficult to discern. Therefore, during the translation process and subsequent self-checking, the translator must carefully read the original text, try to understand the meaning of the original author, pay attention to the coherence of the discourse level, and make the text read naturally by rearrangement, omission, addition and other techniques.

Finally, as the text is related to energy, the translator spent a lot of time browsing and studying related materials and paying attention to the characteristics of the genre in the process of translation practice. When translating, it's important to pay attention to the accuracy of the terminology and the differences between the two languages, and to follow the conventional expressions of the target language. To ensure faithful translation of the original text and alignment with Chinese expression habits, it is necessary to flexibly employ translation techniques and strategies based on context. In

conclusion, to improve translation quality, it is essential to not only acquire theoretical knowledge and practice more, but also maintain a lifelong learning habit. In the context of globalization, new concepts, terms, and expressions continue to emerge. Therefore, translators must have a continuous learning attitude, keeping up with and learning new knowledge to maintain sensitivity and adaptability to language and culture. In addition to individual skills, teamwork, effective communication with other translators, and coordination of progress and quality are crucial for ensuring the smooth running of the entire translation project.

4.3 Limitations

In this translation practice, the translator spent considerable time and effort reviewing the data involved. To ensure accuracy and professionalism, she thoroughly read numerous materials and literature related to the fields of energy, chemistry, and electricity, and consulted experts in these fields. Then, in an effort to achieve the best expression, the translator repeatedly corrected and modified the translation.

Since the translator is not a professional in the field and has no knowledge of the special field in her previous studies and experience, the translation of some contents in the original text is not professional and standardized enough. This shows that her professional terminology and knowledge reserves in certain fields still need to be enriched. In order to improve the professionalism and accuracy of the translation, the translator need to intensify her in-depth study and research in these fields.

Additionally, while the original text is a popular science work, the author occasionally employs anthropomorphic and vivid images to express with a unique personal style and emotional tone. The translator face certain challenges when translating the source text due to the contrast between the rigorous objectivity of the text and the humorous and witty linguistic style of the original author. Therefore, the translator must balance and deal with the difference in language styles to maintain the characteristics of the popular science text while reflecting the original author’s unique style.

In order to improve the accuracy and professionalism of her translations, translator must continuously strengthen her professional knowledge through learning and accumulation. Additionally, translator should be sensitive to different types of texts and authors' language styles to achieve better quality.

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Appendixes

Appendix 1: Glossary

EN	CN
A	
aerodynamic blade profiles	叶片型线的气动性能
alternating current	交流电
B	
biomass	生物质能
bar	巴（气压单位）
C	
carbon dioxide	二氧化碳
climate neutrality	气候中和
chlorophyll	叶绿素
cubic meter	立方米
coal(lignite)	褐煤
coal(anthracite)	煤（无烟煤）
calorific value	热值
crosswind	侧风
concrete	混凝土
D	
density	密度
diesel	柴油
E	
energy flux density	能流密度
electron donor	电子給体
electron abundance	电子丰度
ethanol	乙醇
exajoules	艾焦
F	
flora and fauna	动植物
full load hours	满载小时数
flow velocity	流速
G	
glucoses	葡萄糖
gasoline	汽油
gigawatt hour	吉瓦时
gravitational acceleration	重力加速度
gearbox	齿轮箱

generator	发电机
H	
hydrogen	氢气
hub	轮毂
hemoglobin	血红蛋白
I	
instantaneous power	瞬时功率
installed capacity	装机量
impulse	脉冲
L	
lead-acid battery	铅酸电池
lithium-ion battery	锂离子电池
M	
monocrystalline silicon	纯单晶硅
methane	甲烷
N	
nuclear power	核能
natural gas	天然气
P	
photovoltaics	光伏
photosynthesis	光合作用
photon	光子
petajoules (PJ)	皮焦耳（一百万亿焦耳）
potential energy	势能
pressure gradient	压力梯度
powerplant	发动机
R	
renewable energy	可再生能源
rotor	转子
rated output	额定输出
radial turbine	径流式涡轮
S	
silicium	硅化物
solar collector	太阳能集热器
short power grids	短途电网
radial turbine	径流式涡轮
T	
terawatt hour	太瓦时
transformer	变压器
Three Gorges	三峡水电站
The Banqiao Dam	板桥大坝
the Global Wind Energy Council (GWEC)	全球风能理事会

V	
vibration	震动
W	
wind onshore	陆上风能
wind offshore	海上风能
water electrolysis	电解水制氢
wing	叶片
water drain	排水管
water conduit	导水管

Appendix 2: Source Text and Target Text

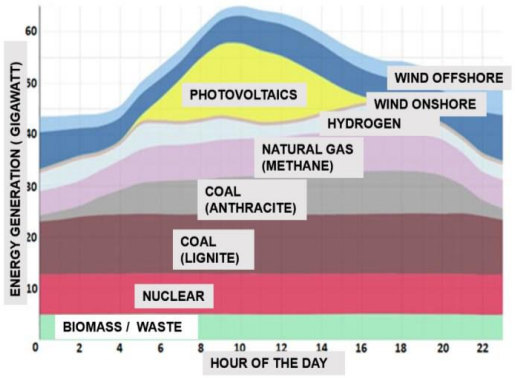
Source Text	Target Text
Part III	**第三部分**
Energy without carbon dioxide	**无二氧化碳排放的能源**
11. The hope-bearers at first: photovoltaics, wind, water	**第 11 节：最初承载希望的：光伏、风能、水能**
The renewable energy sources that provide energy production without carbon dioxide emissions are increasingly being used worldwide: they are indeed the great hope for the desired climate neutrality. However, the account must be made realistically in order not to raise false hopes:	世界越来越多国家使用零碳排放的可再生能源：它们的确是实现气候中和的殷切希望。然而，我们必须要考虑现实因素，以免对可再生能源寄予厚望，结果却希望破灭。
Thesis 25: Photovoltaics, wind and water, ensure almost exclusively electrical energy, but not other forms of energy consumed in the world. In this context is also mentionable, that electrical energy accounts for less than a fifth of the world's energy demand. The contribution of photovoltaic and wind turbines to the production of this electrical energy is worldwide below 10% each.	议题 25：光伏，风能和水能就能发电提供电力，基本上无须消费世界上其他能源。这里要提一下，它们提供的电能占全球能源需求不足五分之一。其中，太阳能和风力涡轮机的发电率均低于 10%。
Of course, photovoltaic, wind and water energy could also be used to heat rooms or water, or to cook steel, but the reality is different. As one of the world's leading	当然，理想状态下，光伏、风能和水能也可以用来让房间暖和，可以加热水，还可以冶炼钢铁。但现实是有差距的。德国是世界上主要的工业

industrial nations, Germany is an enlightening example for this reality, because all modern economic sectors can be found in the energy distribution of the country.	大国之一，国情具有参考意义，在德国，所有现代经济行业都依赖能源的分布情况。
After converting the corresponding data of the German Federal Environment Agency for 2018, the following situation arises: Transport and industry each need around 30% of the total annual energy inflow, as already mentioned in Chapter 9. Households need 25%, commerce 15%. From here on, the utilization of energy should be specified: Transport requires only 1.6% electrical energy, but 94% oil, industry consumes about 30% electrical energy and over 55% gas and coal, households 20% electrical energy, 57% gas and oil, 8% district heating, industry 39% electrical energy, 49% gas and oil.	在对德国联邦环境局2018年的相关数据进行转换后，发现：如上文第9节所述，全年能源总输入中，交通运输业和工业的需求量各占30%左右，户用和商用的需求量则各为25%，和15%。交通运输业的电能利用率仅1.6%，而石油利用率达94%；工业的电能利用率为30%，天然气和煤炭利用率为55%以上，户用的电能利用率为20%，天然气和石油利用率为57%，区域供暖占比 8%，工业的电能利用率达 39%，49%的天然气和石油。此后，环境局应明确规定能源利用率：
As a result, electrical energy accounts for less than 20% of Germany's total energy consumption. On a global scale, electrical energy is involved with 15–17% of total energy consumption (calculated from the annual reports of the International Energy Agency 2016 - 2019). In the production of this electrical energy, all solar plants in the world are involved with 3% compared to	因此，电能仅占德国总能耗的不到20%。在全球范围内，电能占总能耗的15%～17%（根据国际能源署2016年至2019年的年度报告计算得出）。在电能的生产中，全球所有太阳能发电厂所占比重仅为 3%，远低于煤炭和天然气的使用比重。风能占比为 7%，也低于煤炭和天然气的使用

the use of coal and natural gas. Wind accounts for 7% compared to coal and natural gas. Hydropower is almost 10 times more than solar.	比重。水力发电的比重几乎是太阳能发电的 10 倍。
11.1 Photovoltaics	**11.1 光伏**
The average energy flux density of solar radiation (also known as “intensity”, which is not quite physically correct) is 1367 watts per square meter at the boundary of the Earth’s atmosphere. Some of it penetrates into the atmosphere, other parts are scattered or reflected [1]. The proportion of solar radiation that has entered the atmosphere warms the air, the Earth’s and the sea’s surfaces. However, the energy flow coming from solar radiation is also converted directly, in natural processes (photosynthesis in plants) and in technical processes (photovoltaics and photothermal devices).	太阳辐射的平均能流密度（也称为“强度”，但并不完全准确）在地球大气层边界处达到 1367 瓦特/平方米。其中，部分穿过大气层，剩下的则散射或反射[1] 。进入大气层的那部分太阳辐射使空气、地球、海洋的表面温度上升。无论如何，太阳辐射的能量流在自然过程（植物的光合作用）和技术过程（光伏和光热器件）中都可直接转换。
The energy flux density of solar radiation in the Earth’s atmosphere itself fluctuates between zero and 1000 watts per square meter, depending on the Earth region and daily or seasonal fluctuations. Some scientists count, in simplified and idealized scenarios, how much energy the sun supplies to the Earth annually through radiation and then divide this energy to the	地球大气层中太阳辐射的能流密度在 0-1000 瓦特/平方米之间波动，具体密度取决于太阳辐射的地理位置，日辐射情况和不同季节的辐射强度。一些科学家在简化和理想化的情况下，计算太阳每年通过辐射向地球提供多少能量，然后将这些能量除以某一年的世界能源需求。起初结果显示：“太阳提供的能量是

world energy demand of a certain year. What comes out of this is initially **fascinating and energy-hungry-calming**, at least virtually: “The sun provides ten thousand times the energy we need. Why don’t we use them in clever plants, **is it more convenient** for people to tap into dirty energy sources such as oil, natural gas and coal?”	我们实际所需的一万倍。我们何不将此运用在智能化工厂中？难道人们利用石油、天然气和煤炭等非清洁能源**会更方便吗？”这一结果乍看有趣，至少让高能源消耗问题几乎能得到缓解**。
There are several reasons for this:	这有几个原因：
-The flora of this Earth itself needs a lot of the solar radiation, namely from the proportion with the highest intensity (watts per cubic meter), in the wavelength range (micrometers) of the light. The trees and plants use this energy for photosynthesis, which is the engine of their food preparation: With such light rays, the chlorophyll, the green hemoglobin, is activated in the blood of the plant, which then, in two phases, contributes to the conversion of carbon dioxide from the atmosphere and the water at the roots into the nourishing glucoses.	地球上的植物群本身就需要大量的太阳辐射，即光的波长范围(微米)内辐射强度最高(瓦特/立方米)的部分。植物利用太阳辐射的能量进行光合作用，这是它们准备食物的引擎：太阳光照射后，植物体液中的叶绿素和绿色血红蛋白被激活，经过光反应和暗反应的两个阶段后,可以促进大气中二氧化碳和植物根部的水分转化为滋养的葡萄糖。
-The energy flux density (watts/square meter) of solar radiation, as an integral of the intensities on the many wavelengths, is related to surfaces. In order to obtain an energy flow, in this case better known as	作为波长强度的一部分，太阳辐射的能流密度大小（瓦特/平方米）与辐射表面积有关。为了获得能量流（这种情况下，人们对功率（瓦特）更了解），若想每平方米最大功率达

power (watts) at a maximum of 1000 watts per square meter, large areas are required. A practical, current example: On an area of 2700 hectares in China, which is sown with solar panels (the entire Moselle-Saar-Ruwer wine region extends to 8770 hectares), 850 megawatts are harvested. The oil power plant in Ingolstadt provides the same output on 37 hectares, i.e. on 1.37% of the above-mentioned area!	到 1000 瓦，太阳辐射的表面积要广。一个实际的例子：在中国 2700 公顷土地上铺满太阳能板（而整个摩泽尔-萨尔-鲁尔葡萄酒产区面积达 8770 公顷），发电量达到 850 兆瓦。然而，英戈尔施塔特的石油发电厂，仅在 37 公顷的土地上（上述土地面积的 1.37%!）就能达到相同的发电量，
-The sun shines on a surface of the earth only a few hours a day, depending on the latitude – in Ecuador more, in Germany less, if it shines at all. In summer and winter, the intensity of solar radiation is also very different. As an example, a photovoltaic house system in northern Germany, intended for a maximum output of 5 kilowatts, delivers in the summertime (April to September) a total energy of 2880 kilowatt hours, but in winter (November to March) only 1220 kilowatt hours (kWh). The difference between the individual months shows this weather and season dependence even more clearly: In August it is 625 kWh, in January 135 kWh, but in November only 90 kWh! In the entire year, the energy adds up to 4000 kWh. However, with the maximum planned output of 5 kW,	太阳每天照在地球表面只有几个小时，具体时长取决于纬度——如果有太阳的情况下，照射到厄瓜多尔时间更久，照射到德国的时间则少些。夏季和冬季，太阳辐射的强度也不同。例如，德国北部的一个光伏房屋系统，最大输出功率为 5 千瓦，夏季（4 月至 9 月）的总电量为 2880 千瓦时，但在冬季（11 月至 3 月）总电量为 1220 千瓦时（kWh）。以上不同月份的发电量，更清楚地表明了发电量与天气、季节具有相关性：8 月为 625 千瓦时，1 月为 135 千瓦时，但 11 月仅为 90 千瓦时！全年，电量加起来高达 4000 千瓦时。然而，如果计划最大输出功率为 5 kW，理论上一年 8760 小时产生的电量为 43200 千瓦时，但只实现了该值的十分之一！

an energy of 43200 kWh would theoretically be expected in the 8760 hours of a year – but only a tenth of this value was achieved!	
-  Fig. 11 Electrical energy production in Germany, hour by hour, on 16 September 2019 – with different energy sources. The proportion of photovoltaics is marked with yellow (source: Wind Europe, 2019).	ENERGY GENERATION (GIGAWATT): 发电量（吉瓦）: HOURS OF THE DAY: 时长: BIOMASS/WASTE: 生物质能/废料: NUCLEAR: 核动力: COAL(LIGNITE): 褐煤: COAL(ANTHRACITE): 煤（无烟煤） NATURAL GAS(METHANE): 天然气（甲烷） HYDROGEN: 氢能 WIND ONSHORE: 陆上风能 PHOTOVOLTAICS: 光伏 WIND OFFSHORE: 海上风能 图 11 2019 年 9 月 16 日德国使用不同能源,每小时的电能产量。光

	伏发电的比例用黄色标出（资料来源：Wind Europe, 2019）。
Fig. 11 illustrates the time-dependence of the electrical energy obtained by photovoltaics in the whole Germany, compared to the production of electrical energy using coal, gas, hydroelectric and nuclear power plants. If the sun were shining day and night at maximum intensity, the contribution of photovoltaics would be significant.	与使用煤炭、天然气、水电和核电厂发电量相比，图 11 表明整个德国光伏发电量受时间影响。如果太阳日夜以最大强度照射，那么光伏发电的贡献将是巨大的。
But how at all does the sun do that? In plants, the sun rays encounter at first chlorophyll and activates it. In photovoltaic panels the sun rays meet silicium instead chlorophyll!	但是光伏发电原理是什么呢？太阳光照到植物上，会先激活叶绿素。然而，在光伏电池板中，太阳光线会先照到硅化物而非叶绿素！
Silicium is available everywhere. **Silicium with two oxygen atoms** forms the billions and billions of grains of sand in the deserts and beaches of the earth. In combination with oxygen, silicium is utilized as glass: glass for the wine, glass for the windows, glass for the greenhouse. And **as for the greenhouse**, so also for the hot water modules (solar collectors) in the photothermal systems for water heating. A glass surface allows sun rays in the wavelength range of light to pass through. However, when the sun's rays have	**硅化物**随处可见。地球沙漠和海滩上数以亿计的沙粒中都含有**二氧化硅**。与氧原子结合，硅化物就可以用作玻璃：葡萄酒玻璃，窗户玻璃，温室玻璃。用于加热水的光热系统中，热水器（太阳能集热器）**和温室的原理一样**。一定波长范围内的太阳光线都可以穿过玻璃表面。然而，当太阳光将其部分能量，如热量，照到玻璃后面的房间或植物时，光线的强度会减弱，电磁波的振动也会变慢。然而，对于这种振荡来说，二氧化硅太硬了，有时不会让两个氧原

transferred some of their energy, as heat, to the room or plants behind the glass surface, their intensity is weakened and the vibrations of their electromagnetic waves become slower. However, the silicium with its two oxygen atoms is too rigid for such oscillations and sometimes does not let them out. And so, everything behind the pane becomes warmer and warmer if the corresponding volume is well insulated.	子溢出来。因此，如果相应的温室空间隔离做得好，那温室里的一切都会越来越暖和。
In a photovoltaic cell, the silicium has no oxygen atoms, but other partners. In 1839, the French physicist Becquerel stated that “a release of (electrical) charge carriers can occur through light”. An electron can therefore detach from an atom if it has eaten energetic photons from the sun’s ray.	光伏电池中，硅化物不和氧原子共同作用，而是和其他元素。1839 年，法国物理学家贝克勒尔（Becquerel）指出，“光生电荷载流子。“由此得出，如果电子吸收了来自太阳光线的高能光子，就可以从原子中分离出来。
And such a phenomenon opens the way for inestimable applications!	此后，光电效应为光伏的广泛应用开辟了道路！
The upper silicium layer of a photovoltaic cell is interspersed with electron donors, usually phosphorus atoms. This results in an excess of electrons in the structure of the upper layer. The lower silicium layer, in turn, is interspersed with boron atoms and as a result has electron deficiency, i.e. holes in the structure of the lower layer.	光伏电池的上硅层与电子给体（通常是磷原子）交错，导致上层结构中电子过剩。而下硅层与硼原子交错，因此缺少电子，下层结构中就存在空穴。
Interesting, however, is the intermediate layer, as a boundary area between electron	然而，有趣的是中间层，它是电子丰度和电子缺乏之间的边界区域：该

abundance and electron deficiency: There electrons sit in holes, but they sit like in starting blocks, ready to start somewhere as soon as there is created at least one impulse. And now the light rays come into play: they collide with the upper layer of the photovoltaic cell, their photons, fully charged with energy, push up to the boundary layer of the cell and give the electrons in the starting blocks the welcome impulse. They hiss upwards, towards the cell surface. This movement develops as a true chain reaction, in the middle layer an electron suction is formed, the lower layer supplies electrons and thus has even more holes.	区域内，电子由空穴包围着，就像处在起动块中一样，一旦有至少一个脉冲，它们就随时准备启动。现在光线开始发挥作用，与光伏电池的上层相撞，充满能量的光子将电子推到电池的边界层，给起动块中的电子一个激励的脉冲。这些电子朝电池表面，嘶嘶地向上移动。电子运动过程中形成了真正的连锁反应，中间层形成电子吸力，下层提供电子，因此，产生了更多空穴。
Between the upper and the lower layer, an electrical voltage is thus created. The current can be tapped using appropriate contacts at the top and bottom. The contacts are connected to a **consumer** via **cables**. Such a consumer can be a light bulb or contact an electric motor. The electrons from the upper layer flow through the consumer to the lower layer and so the circle closes. Then the light rays with energetic photons come again through the upper layer to the boundary layer and the game begins again.	而后，上层和下层之间产生了电压。通过顶部和底部适当的触点分接电流。触点再通过**电缆**连接到**用电设备**——可以是一只灯泡也可以是一台电动机。此时，上层的电子流经用电设备再流向下层，形成完整的电路闭环。然后带有能量光子的光线再次穿过上层到达边界层，开始循环往复。

However, the process is at some time saturated in this vertical plane, because in the upper- and lower-layers electron abundance and electron deficiency in the structure have a physical limit. Consequently, many such "shafts" are required on the horizontal plane, i.e. more area with photovoltaic cells.	然而，在这个垂直平面上，这个循环往复的过程有时会达到饱和，因为上下层结构中的电子丰度和电子缺乏有一个物理极限。因此，水平平面上需要许多这样的“轴”，即光伏电池的面积更大。
The fact that the energy flux density of solar radiation in the Earth's atmosphere itself fluctuates between zero and 1000 watts per square meter has already been mentioned. However, photovoltaic cells are expected to achieve the 1000 watts, i.e. 1 kW of power, on a panel with an area of 1 square meter. Unfortunately, **this** does not work. Even with pure monocrystalline silicon, the efficiency of the described process is not higher than 24%. So, you would need 4.17 square meters of panels to reach 1 kilowatt of power with maximum solar radiation. In practice, however, it is 5 to 10 square meters because the silicium crystals are not absolutely pure, often the cheaper polycrystals being used. Compared to the calorific value of a fuel such as gasoline, diesel or ethanol, this energy amount is rather poor.	上文提到，地球大气层中太阳辐射的能流密度在 0-1000 瓦特/平方米之间波动。人们就指望光伏电池能在 1 平方米的面板上实现 1000 瓦的功率，即 1kw 的功率。可惜，行不通。即使使用纯单晶硅，上述过程的效率也不会高于 24%。因此，假设在太阳辐射最强的情况下，要达到 1000 瓦功率，则需要 4.17 平方米的面板。然而，在实践中，需要 5 到 10 平方米的面板，因为硅晶体并不绝对纯净，会使用成本更低的多晶硅。与汽油、柴油或乙醇等燃料的热值相比，硅晶所产生的能量很少。

Thesis 26: Ten square meters of photovoltaic panels can provide during a summer day with 8 hours of solar radiation, as much energy (8 kWh) as 1 liter of burning gasoline or as 1.7 liters of pure ethanol from rotten apples or plant residues, or as four liters of forty percent fruit spirit.	议题 26：在夏季 8 小时的太阳辐射下，十平方米的光伏电池板能产生 8 度电（8 千瓦时），就相当于 1 升汽油燃烧后的发电量或腐烂苹果、植物残渣产生的 1.7 升纯乙醇的发电量或 4 升 40%水果酒精的发电量。
Very large-scale and very small photovoltaic systems are installed far and wide in the world. In order to always put them in the best light, operators, sellers and eco-militants use bombastic units of measurement that hardly any layman understands:	世界到处都安装了大型、小型光伏发电系统。为了始终让它们处于最佳运行状态，运营商、销售商和生态活动家们大量使用了几乎只有内行人懂的计量单位。
- for the power output: kilowatts, megawatts, gigawatts;	- 功率输出：千瓦、兆瓦、吉瓦；
- for the energy that results from such construction per year: kilowatt hour, gigawatt hour, terawatt hour, but also exajoules and petajoules, and even megatons of oil units (1 MTOE is the same as 11.63 terawatt hours).	- 每年此类建筑产生的能量：千瓦时、吉瓦时、太瓦时，以及艾焦（10^18 焦耳)和皮焦(10^12 焦耳)，甚至兆吨（石油单位，1 兆吨相当于 11.63 太瓦时）。
No one has started quadrillions of kilocalories yet, but therefore it's never too late. It took some time and effort to centralize such data, standardize it and evaluate all that information for this book, according to objective criteria.	目前还没有人开始计算四万亿千卡热量。虽然根据客观标准，收集这些数据，对其进行标准化，再评估本书的所有信息，费时费力，但为时不晚。

A first, very pragmatic criterion is the ratio of the energy collected during a year, standing out against wind and weather, through summer and winter, through day and night to the installed (and hoped-for) power of the plant. The best integrator of energy and performance is the planet itself! In 2018, all the photovoltaic systems in the world have had a peak output of 500,000 megawatts (MW) – which was calculated for ideal, best conditions. All these systems together generated in the year 2018 a total, real electrical energy of 600 billion kilowatt hours (kWh).	首先，一个非常实用的标准是，在一年中，无论风吹日晒，寒冬酷暑还是白天黑夜，所收集的能量与发电厂的装机（和预期）功率之比。地球自身就是能源和性能的最佳集成器！2018 年，全球所有光伏系统的峰值输出功率达到 50 万兆瓦（MW）--这是在理想的最佳条件下计算得出的。所有这些系统在 2018 年总共产生了 6000 亿千瓦时（kWh）的实际电能。
In comparison, in the same year, in the world have been produced 9851 billion kWh with coal and 5890 billion kWh with gas. so total with coal and gas 15,471 billion kWh. The electrical energy generated by photovoltaics therefore accounts for 3.8% of the electrical energy from coal and gas. Compared to all energy sources and plants used for electricity production worldwide, the contribution of photovoltaic systems was only of 2.3%.	相比之下，同年，全球煤炭发电量为 98,510 亿千瓦时，天然气发电量为 58,900 亿千瓦时。煤炭和天然气发电量总计 154,710 亿千瓦时。因此，光伏发电产生的电能占煤炭和天然气发电量的 3.8%。与全球用于发电的所有能源和发电厂相比，光伏系统的发电率仅占 2.3%。
But another aspect is also interesting: If the calculated power of 500,000 MW could have been achieved continuously throughout the year, the total energy	但另一方面也很有意思： 如果全年都能连续发电 500,000 兆瓦，那么总发电量将达到 43,800 亿千瓦时。让我们将现实与计划进行比较：

produced would be 4380 billion kWh. Let us compare reality with schedule: 600 billion kWh (actual) by 4380 billion kWh (target) results in a rather humble ratio of 0.137!	6000 亿千瓦时（实际发电量）除以 4380 亿千瓦时（目标发电量），得出的比率相当低，仅 0.137！
Thesis 27: The solar radiation fluctuating over all the day, over all the latitudes and over all the seasons on all photovoltaic systems in the world results in an annual average global radiation efficiency of 13.7%.	议题 27：全球所有光伏系统全天、各纬度、各季节的太阳辐射波动导致全球年平均辐射效率为 13.7%。
As a comparison, in Germany in the same year 2018 there were photovoltaic systems with a peak output of 45,500 megawatts calculated for ideal, best conditions. In that year, they generated a total electrical energy of 45.7 billion kilowatt hours (kWh) in Germany. The radiation efficiency in Germany in 2018 is therefore 11.4%. This is less than the global efficiency of 13.7%, which can be explained by latitude and weather. The largest photovoltaic plants in the world have been even built in very sunny regions.	相比之下，2018 年德国的光伏系统在理想情况下的峰值输出功率为 45,500 兆瓦。这一年，它们在德国发电量达到 457 亿千瓦时（kWh）。因此，2018 年德国光伏系统的辐射效率为 11.4%。这低于全球 13.7% 的辐射效率，主要是纬度和天气原因。世界上最大的光伏电站都建在阳光非常充足的地区。
In Benban, Egypt, a photovoltaic plant with a calculated peak output of 1800 megawatts (MW) was built in the desert near Aswan (earth observatory. nasa, 10/2019). In Abu Dhabi, a plant with 1177 MW is under	**例如：**埃及本班，阿斯旺附近的沙漠中建成了一座光伏电站，计算峰值输出功率为 1800 兆瓦（MW）（美国国家航空航天局地球观测站，2019 年 10 月的数据显示）。阿布扎比的

construction, in Longyangxia, China, in the desert near the city of Hainan, a photovoltaic plant with 850 MW was built on 2700 hectares (2017), which, according to Chinese data, secures the supply of electrical energy for 200,000 residences. Converted on the basis of the global radiation efficiency 2018 as a guideline, this results in an electrical energy of around 700 kWh per house and year. The guideline value for Germany is, in comparison, 8,000-14,000 kWh for a single-family house with 4 people, with its own solar system with a peak output of 6 kW.	一座 1177 兆瓦的光伏电站正在建设中。羊峡是中国海南州附近的一片荒地，那里建成了一座占地 2700 公顷（2017 年），输出功率为 850 兆瓦的光伏电站，根据中国的数据，该电站可保障 20 万户居民的供电。以 2018 年全球辐射效率为准则进行换算，每户每年可获得约 700 千瓦时的电能。相比之下，德国的指导值为：一家四口住的独栋住宅，自带峰值输出功率为 6 千瓦的太阳能系统，用电量达 8,000-14,000 千瓦时。
In China, another large plant with 2000 MW is currently being built (02/2020). In Kamuthi, India, there is a plant with 648 MW, in California, USA, the Topaz Solar Park with 579 MW, consisting of 1.7 million solar panels. The largest solar plant in Germany (07/2019) is located in Brandenburg and has a peak capacity of 145 MW.	中国目前正在建设另一座 2000 兆瓦的大型发电站（2020 年 2 月）。印度卡穆提有一座 648 兆瓦的发电站；美国加利福尼亚州的 Topaz 光伏发电站的发电力为 579 兆瓦，由 170 万块光伏电池板组成。德国最大的太阳能发电厂（07/2019）位于勃兰登堡，峰值发电力为 145 兆瓦。
After the dessert, photovoltaics also make way at sea: In China, a "floating photovoltaic system" with 40 MW was built. The 132,400 panels occupy an area of 93 hectares on the water. Due to **the better**	除了沙漠荒地，光伏技术在海上也大展身手：中国建造了一个 40 兆瓦的 ″浮动光伏系统″。由 132,400 块电池板组成，水上面积为 93 公顷。由于水面上**电池冷却效果更好**，

cooling of the cells, this system has a higher efficiency than that on the ground.	该系统的在水面上的效率高于在地面上.
In Europe, whether in Italy or in Germany, people have recently started talking about "agro-photovoltaics". There are already plants with vertical panels in the field, in between grow carrots, potatoes and other vegetables. It is even said that they grow better than usual, due to the light radiation reflected by the panels. The second European variant is the one with panels at a certain height above the pastures, so that the sheep below can eat their grass undisturbed. Such extravagant individual solutions in areas with intensive agriculture and rather moderate solar radiation, such as in Europe, are interesting showcase projects with too little of the energy production of the respective country.	在欧洲，无论是意大利还是德国，人们最近开始谈论“光伏农业一体化”。田间植物四周都安装了垂直面板，其间胡萝卜、土豆和其他蔬菜。甚至有人说，由于面板反射的光辐射，它们比平时生长得更好。第二种欧洲的改良版是在牧场上方一定高度安装面板，这样下面的绵羊就可以不受干扰地吃草。在欧洲等农业密集、太阳辐射相当温和的地区，这种奢侈又独特的解决方案是具有吸引力的展示项目，但各国的产能太少。
On the other hand, as in the examples shown, the construction of large photovoltaic systems in deserts and in areas with particularly strong and long-lasting solar radiation, such as in Australia, Kenya, Egypt, China, Dubai, Indonesia, Nevada or Colombia, seems to make sense. Using short power **grids**, they can efficiently supply the mostly existing **grids** in neighboring cities with electrical energy in	另一方面，如上述例子所示，在沙漠和太阳辐射特别强、持久的地区，如澳大利亚、肯尼亚、埃及、中国、迪拜、印度尼西亚、内华达州或哥伦比亚，建造大型光伏系统似乎是有意义的。在混合式供电网络中，利用短途**电网**，可以有效地为邻近城市的现有**电网**供电，全时段稳定，不受天气影响。

an electricity mix, regardless of fluctuation throughout the day and depending on the weather.	
In addition to the large-scale plants, the individual, in-house plants in Europe and elsewhere in the world appear to be reasonable and efficient. A system with about 35 square meters on the roof of a single-family house in Germany provides an electrical energy of 8,000-14,000 kWh per year when exposed to solar radiation, which is usually sufficient for a family of four persons. It should be noted that due to the fluctuation of solar radiation, especially in the day-night rhythm, a power storage system is absolutely necessary. Lead-acid batteries, more recently lithium-ion batteries, as in electric cars, are usually used for this purpose.	除了大型工厂外，欧洲和世界其他地方的个别内部工厂似乎合理高效。在德国，一个 35 平方米的单户住宅屋顶上的系统，在太阳辐射下，每年可以提供 8000 – 14000 千瓦时的电能，通常可供四口之家使用。需要注意的是，由于太阳辐射的波动，特别是在昼夜节律中，蓄电系统是十分有必要的。从铅酸电池到最近电动汽车中使用频率更高的锂离子电池，都是用于蓄电。
Unfortunately, future-oriented techniques, especially in the field of energy or automotive propulsion, are very often regarded as universal approaches with a world-saving character. All alternatives then suddenly “have only serious disadvantages”. And if the new technology still has problems, they are passed over by means of true science fiction scenarios. This is also the case with photovoltaics.	遗憾的是，未来的技术，尤其是推进能源或汽车领域发展的技术，往往被视为可以拯救世界的通用方法。一夜之间，其他所有替代方案都“毫无优势”。如果新技术仍然存在问题，就用看似真实的科幻场景忽略这些问题。光伏技术也是如此。

“The fluctuation of the produced electrical energy over the day or over the season is not a disadvantage in itself, but a natural condition from which everyone can make the best. The placement of a large plant close to the large power grid of a city is such a compromise, the small system on the house, completed with a battery with a reasonable capacity, the other”.	“产生的电能在一天或一季中的波动本身并非缺点，而是一种自然条件，人人都能从中获益。在靠近城市大型电网的地方建立大型发电厂是一种折中办法，在家里建立小型系统，并配备合理容量的蓄电池，则是另一种折中办法”。
But the idea that with the very weak yield compared to an energy source such as ethanol from plant residues, the photovoltaic participation in the world's electrical energy can be increased from the current 2.3% to 30 or even to 50% is very exaggerated.	但是，与植物残渣中的乙醇等能源相比，光伏发电的产量非常低，因此可以将其在世界电能中的占比从目前的 2.3%提高到 30%甚至 50%，这种想法是非常夸张的。
Of course, you could sow all the deserts of the world with photovoltaic systems, why not, they are empty anyway and the human settlements are usually very far.	当然，你可以在世界所有沙漠地区装满光伏系统，为什么不呢，荒芜的沙漠很适合，而且人类住所通常也相隔甚远。
And what happens to the fluctuation of energy day and night, and how do you transport this energy from the desert to Berlin or New York?	那么，这些能量昼夜波动情况如何，又如何将它们从沙漠运输到柏林或纽约？
People talk about thousand-kilometer routes of pipelines - in Germany, for example, they debate them for a very long time, in connection with wind and solar parks, so far without clear results.	人们谈论着长达数千公里的管道线路——例如，在德国，他们长期争论风能和太阳能园区相关的管道线路，但迄今为止，结果尚未明确。

People talk about gigantic batteries – especially in the desert, at 50°C. Well, you can then put a large power-guzzling air conditioner next to it, how imaginative!	谈及巨型电池——特别是沙漠中50° C 高温。 好吧，然后你可以在旁边放一个大功率空调，多么富有想象力！
But the foolhardiest idea is another: you could use the electricity on site for water electrolysis (if you have enough water in the area) to produce hydrogen. The hydrogen, as a carbon dioxide-emission-free energy carrier, can then be transported over thousands of kilometers with giant trucks, such as the 50-meter- long road trains, from Australia to Europe or elsewhere. Hydrogen can then be used in power fuel cells, and so on. There is only one catch: hydrogen as a gas has a density 15 times lower than atmospheric air. An example of where this leads: In a 60 liter automotive tank at atmospheric pressure and at 40 ° C, there would be 4.6 grams of hydrogen in the tank, with a calorific value equivalent to 14 grams of gasoline. Of course, you can compress the hydrogen at 600-900 bar, or cool it to minus 253 °C, as in **fuel cell** systems for automobiles. The road train through the desert would then either become a moving bomb or a mobile large cold chamber.	不过，还有一个更荒唐的想法，你可以在现场用电解水制氢（如果该地区有足够的水）。氢气，作为一种无二氧化碳排放的能源载体，可以用大型卡车（如 50 米长的公路列车）从澳大利亚运送到欧洲或其他地方，行程可达数千公里。而后，氢气可用于动力燃料电池等。只有一个问题：氢气密度比大气中的空气低 15 倍。例如，在 60 升汽车油箱中，大气压和 40° C 下，油箱中有 4.6 克氢气，其热值相当于 14 克汽油。当然，当然，你可以把氢气压缩至 600-900 巴，或者像汽车**燃料电池**系统那样，将其冷却到零下 253 摄氏度。通过沙漠的道路列车要么成为移动炸弹，要么成为移动的大型冷室。

Of course, the idea with the pipeline remains, like Nordstream 2. Sounds utopian, is utopian: With the lowest density of all elements, this gas would need pipelines with extremely large diameters, especially at high temperatures, in order to be able to transport a sufficient mass flow of hydrogen in a streaming volume. On the other hand, hydrogen already ignites at 4% concentration in the air. A small leak in the pipeline at 40°C in the desert would cause a disaster.	当然，管道运输也是一种办法，就像 Nordstream 2 一样。理想很丰满，现实的确很丰满：由于氢气密度最低，尤其是在高温下，为了运输足够质量的氢气，要使用大直径的管道来增加氢气的流量。以便以流动体积输送足够质量的氢气。另一方面，当空气中氢气浓度达到 4%，就会燃烧。沙漠中，如果气温达到 40° C，管道即便是发生轻微泄漏，都会造成灾难。
It is indisputable that people on earth absolutely need emission-free photovoltaic energy. However, this is not a universal solution, but **a good addition to a reasonable energy mix.**	无可争议，人类十分需要无排放的光伏能源。虽然，这个解决方案并非万能的，但是**添加光伏能源较合理地（完善了）混合式能源结构。**
The sun comes to the atmospheric border with a charge of 1347 watts per square meter, within the atmosphere only 1000 remain, the solar panels keep only 100 to 200 of them, over the year, with all fluctuations, only 12 to 14 watts remain per square meter. From a thousand to twelve, that's 1.2%.	太阳光照到大气边界时，每平方米的能量为 1347 瓦，大气层内，只剩下 1000 瓦，太阳能电池板只保留其中的 100 到 200 瓦，一年内，所有波动后，最终每平方米只剩下 12 到 14 瓦。从 1000 瓦到 12 瓦，只有 1.2% 的能量被太阳能电池板利用。
Nevertheless, we need these percentages, whatever the cost. In this analysis, nothing was deliberately said about prices that are actually reasonable – it is basically about	但是，不惜一切代价，我们都需要这些数据。在这一分析中，并未刻意提及实际合理的价格 ——即使只有几个百分点，基本上是为了减少人

diminishing anthropogenic carbon dioxide emissions, even if only a few percent.	为的二氧化碳排放。
Thesis 28: In the deserts of the world, as an electric energy supplier in nearby cities and on family homes all over the world, as a decentralized power supply, photovoltaics is particularly efficient. But covering entire cities and fields with it would neither increase efficiency nor be humane. Berlin doesn't need "Under the Panels", under the lime trees (“Unter den Linden”, in German, a famous street in Berlin) are more beautiful!	议题 28：在世界沙漠中，铺设了分布式光伏发电系统，为附近城市和世界各地家庭住宅供电，发电效率极高。但若用它覆盖整座城市和区域，既不会提高发电效率，也不人道。柏林不需要“光伏发电板”，菩提树下的柏林更美（ 德语“Unter den Linden”，为柏林菩提树大街，是柏林著名的街道）
11.2 Wind power	**11.2 风能**
Power alone is not enough, we need work for the generators that have to produce a reasonable amount of electric energy during a passable duration, not only for few minutes. Work means power over a period of time. This formula results from the basic definition of work as a force acting over a distance.	仅有电力是不够的，我们还需要发电机的工作，在可通过的时间内，而非短短几分钟，发电机需要保持正常的运行状态，确保产生足够的电能。 功是指一段时间内的功率。这个公式源于功的基本定义，即作用在一定距离上的力.
An **instantaneous power** in a **wind power plant** is nothing else than the flow of kinetic energy that the wind brings with it. This flow of kinetic energy is given by the multiplication of the mass flow of the air (kilograms per second) with the half of squared speed of the wind (square meters	**风电场**的**瞬时功率**就是风带来的动能流。这种动能流是由空气质量流量（千克每秒）乘以风速平方的一半（平方米每平方秒）得出的。质量流量本身可以表示为空气密度、空气速度和流截面（由风力涡轮机转子形成的正面区域）的乘积。因此，在

per square second). The mass flow itself can be expressed as a product of air density, air speed and flow-cross section (the frontal area formed by the rotor of the wind turbine). And so, appears in this deduction of a power formula, the air speed to the power of three, a cubed speed!	功率公式的推导中，出现了风速的三次方，即速度的立方！
The instantaneous power (joule per second, which is equal to watts), can be high, when the wind blows, or zero, when the air is still. At the end of the year, any large or small amount of power will be added for all the seconds or hours of the year (watt-second, watt-hour or kilowatt-hour), so the work comes to light as energy throughout the year.	风吹过时，瞬时功率（焦耳每秒，等于瓦特）可能很高，空气静止时，瞬时功率可能为零。年底，所有秒或小时都将增加任何大小功率（瓦特秒、瓦特小时或千瓦小时），因此全年工作都以能量形式出现。
Sorry for this annoying theory, but it allows to discover a very sensitive point of the power of a wind turbine: the cubed air speed!	很抱歉提出这个烦人的理论，但它让我们发现了影响风力涡轮机功率的一个关键点：风速的立方
Thesis 29: The instantaneous power of a wind turbine mainly depends on the cubed wind speed. Between 5.4 km/h and 25 km/h, the power output increases a hundred fold, maintaining the same air density.	论题 29：风力涡轮机的瞬时功率主要取决于风速的立方。在 5.4 公里/小时至 25 公里/小时之间，输出功率增加了一百倍，保持相同的空气密度。
In Germany, for example, four wind zones have been defined by the norm DIN 1055-4: they range from a maximum wind speed of 81 km/h (Zone I, Germany Central and	例如，德国的四个风区是以 DIN 1055-4 为标准定义的：它们的范围从最大风速 81 公里/小时（从 I 区，

Southwest) to 108 km/h (Zone IV, coasts in Northern Germany).	即德国中部和西南部）到 108 公里/小时（到IV区，即德国北部的海岸）。
Historically, people have probably utilized wind for as long as fire to gain energy: from a windmill for work, from a fireplace for heat.	历史上，人们利用风力发电的时间可能与利用火力发电的时间一样久。风能转化为机械能，火燃烧散发热能。
The first mention of windmills can be found in Babylonian writings from the 18th century BC. In Europe, windmills were mentioned in England in the 9th century, in France in the 11th century and in the 13th century. In the 19th century there were already over a hundred thousand of them on the continent, 9,000 only in Holland. Some of these windmills achieved power outputs of up to 30 kilowatts. The first wind turbine for electricity generation appeared in 1887, in Scotland. A decade later, aerodynamic **blade profiles** were developed in Denmark, which greatly reduced the number of rotor blades. The large-scale use of wind turbines began after the historic oil crises of the 1970s.	公元前 18 世纪，巴比伦著作中首次提及风车。在欧洲，例如 9 世纪英国、11 世纪以及 13 世纪的法国都出现了风车。甚至在 19 世纪，欧洲大陆上已有 40 多万台风车，仅在荷兰就有 9,000 台。其中一些风车的输出功率高达 30 千瓦。世界首台用于发电的风力涡轮机于 1887 年在苏格兰问世。十年后，基于空气动力学理论，丹麦研发出的**叶型**极大地减少了转子叶片的数量。20 世纪 70 年代，历史性的石油危机之后，风力涡轮机开始大规模运用。
The reorientation of the energy industry in many countries around the world towards renewable energy sources, **which was caused by these oil crises**, has significantly accelerated the construction of wind turbines.	**石油危机导致**许多国家的传统能源行业公司开始向可再生能源转型，大大加快了风力涡轮机的建设。

Since then, onshore wind turbines have been springing up like mushrooms, and in Germany alone there were around 30,000 of them at the end of 2019 (Statista 2020). On the water, i.e. offshore (off the coast), there are now more than 5500 wind turbines worldwide (11/2019).	而后，陆上风力涡轮机如雨后春笋般涌现，仅在德国，2019 年底就有约 30,000 台（Statista 2020）。在水面上，即近海（沿海），现在全球有超过 5,500 台风力涡轮机（11/2019）。
Onshore wind turbines achieve capacities between 2 and 5 megawatts (MW), the offshore turbines generally have the better wind in terms of air density and speed, which is why their power spectrum is also higher, at 3.6 to 8 MW.	陆上风力涡轮机的单机容量在 2-5 兆瓦之间，由于海上空气密度和速度更平稳，因此，风力更大，可以带动风力涡轮机旋转。同时，海上风机转动时的空气密度和风速比陆上更大。因此，它们的功率谱也更高，在 3.6 到 8 兆瓦之间。
However, performance alone is a quantitative, not a qualitative, criterion. The energy efficiency of a wind turbine must be able to measure up to that of a photovoltaic cell: If the sun enters with 1000 watts per square meter of cell area, and only 100-200 watts of it can be converted, what about the power provided by the wind on the wind turbine circular surface?	然而，性能本身是一个量化标准，而非定性标准。风力涡轮机的能源效率必须与光伏电池的一致：太阳光照射到光伏电池上的功率为 1000 瓦/平方米，而其中只有 100-200 瓦能转换发电，那么风吹在风力涡轮机圆面上的功率为多少呢？
There are strongly differing figures on the area-related performance of wind turbines. This is no wonder considering that the air velocity is calculated high three, which is why small gusts can have a big impact. In a 2015 theoretical study which is	风力涡轮机的区域性能差异很大。这也难怪，计算结果显示，空气速度很快的情况下，一小阵风都会有很大风力。凡是有关风力涡轮机的论文[2]，都会偶尔引用 2015 年的一项理论研究，该研究发现，风机能源转

occasionally cited in papers about wind turbines [2], appears as a strange calculation result regarding the energy efficiency: 1 watt per square meter as the upper limit!	换效率的上限为每平方米一瓦，这一结果令人不解。
This perspective takes indeed the wind out of the sails of every wind turbine fan! Admittedly, this simulation was not done for a wheel, but for an entire wind farm, using the wind movements on an area of 100,000 square kilometers in Kansas, USA. It can be read that the wind falls mainly from the sky, i.e. vertically, and only swirls on the ground, which is why the horizontal speed components are rather negligible. What, if a man in Bremen, Germany, would hear that fighting on the street against a crosswind of 108 km/h! Admittedly, in the wind farm not only the areas in front of the wind turbine rotors count. It is also a fact that the more wheels there are in a wind farm, the less power each of them provides, due to the air braking by the rotor blades. Nevertheless, simulation experts, as well as nascent engineers, should complete at least one semester of internship in the real economic or industrial world!	这个观点属实令所有支持风力涡轮机发电的人们丧失信心！诚然，该实验模拟的对象并非一个叶轮，而是整个风力发电厂，利用美国堪萨斯州 10 万平方公里内的风来完成模拟试验。可以看出，风主要是直接吹往地面，也就是垂直方向吹，仅在地面打转，因此水平方向的风速几乎可以忽略不计。如果走在德国不来梅州的街上，你会经常听到有人就侧风的风速是否为 108 公里/小时而争论不休。诚然，在风力发电厂中，不仅是风力涡轮机转子前的区域算数。还有一项事实是，由于转子叶片的空气制动作用，风力发电厂中风叶轮越多，每个轮子提供的动力就越少。尽管如此，模拟的专家们以及新入行的工程师，应该在现实经济，工业社会中至少完成一学期的实习！
The Walney offshore wind farm, UK, consists of 2 x 51 Siemens wind turbines, each with 3.6 megawatts, which occupy a	英国沃尔尼海上风电场有 2 x 51 台西门子风力涡轮机，每台风力涡轮机的功率为 3.6 兆瓦，在水面上占据

total area of 73 km2 on the water. The distance between the individual wheels, arranged in rows, is 749 to 958 meters. The total power of all wheels of 367.2 MW due to the total area of 73 km2 would be 5 watts per square meter at full load. Not only the area in front of each wheel, but also the water surface between the wheels was considered in order to be able to evaluate the overall efficiency of such a wind farm.	的总面积为 73 平方公里。成排排列的各风叶轮之间的距离为749至958米。由于总面积有 73 平方公里，所有风叶轮的总功率达到 367.2 兆瓦，在满负荷的情况下，每平方米功率达到 5 瓦。为了能评估这样一个风电场的整体效率，不仅考虑了每个叶轮前面的区域，而且还考虑了叶轮之间相隔的水面距离。
On the other hand, the wind does not blow all year round at the speed planned for the maximum power of a wheel. And so, the full load hours came into play: these “full load hours” during a year, multiplied by the theoretical maximum power, should result in the same energy that was achieved in actual operation with the speed-related power fluctuations (instantaneous power) in all 8760 hours of that year. Depending on location and turbine design, wind turbines reach 1400 to 5000 full load hours per year. At 8760 real hours per year, this results in a degree of utilization of 16% to 57% (The global radiation efficiency in photovoltaic systems was 13.7%, according to thesis 27).	另一方面，风并不是一年四季都以计划中的速度吹向叶轮产生最大功率。于是，满发电小时数开始发挥作用：一年中的这些 “满发小时数”，乘以理论上的最大功率，应能得出全年 8760 小时内与速度有关的功率波动（瞬时功率）的实际发电的能量。根据位置和涡轮机的设计，风力涡轮机每年达到 1400 到 5000 个满发电小时。在每年 8760 个实际小时中，这导致 16%到 57%的利用程度（根据论题 27，光伏系统的全球辐射效率为 13.7%）。
Onshore plants in Germany have reached an average of around 1640 full-load hours in recent years. It is expected that in the future	近年来，德国的陆上风电场平均达到了约 1640 个满发小时。预计在未来，陆上电厂的满发小时数将平均

the onshore plants will reach an average of 2250 full-load hours and the offshore plants 4500 full-load hours [3]. In the USA, onshore wind turbines reach 2600 - 3500 full **load** hours, which corresponds to a utilization rate of 30 - 40% [4]. Recently, attempts have been made to compensate the fluctuations in wind speed by means of "weak wind turbines" with a particularly large rotor area, around 5 m2/kW, whereby the number of full load hours increases to about 4000.	达到 2250 个小时，海上电厂将达到 4500 个满负荷小时[3]。美国陆上风力涡轮机的满**载**小时数达到 2600 - 3500，相当于 30 - 40%的利用率[4]。最近，人们试图通过转子面积特别大（约 5 平方米/千瓦）的 "弱风涡轮机 "来补偿风速的波动，从而使满发电小时数增加到约 4000 小时。
A comparison of the performance yields per square meter between photovoltaic plants and wind turbines seems to be appropriate at this point: How do we make better use of the space in the future, with solar systems or with wind turbines?	在这一点上，比较光伏电站和风力涡轮机每平方米的性能产量似乎是合适的：我们如何在未来更充分地利用空间，用太阳能系统还是用风力涡轮机？
The very modern onshore GE model Cypress (02/2020) wind turbine has a maximum calculated output of 5.3 megawatts and a rotor diameter of 158 meters, which corresponds to a wind flow area in front of the rotor of 19,596 square meters. This results in 265 watts per square meter. The Vensys wind turbine, with a rated output of 5.6 MW and a rotor diameter of 170 meters, achieves around 240 watts per square meter. On the other hand, the	非常现代的陆上通用电气模型 Cypress（2020 年 2 月）风力涡轮机的最大计算输出为 5.3 兆瓦，转子直径为 158 米，相当于转子前方的风力面积 19,596 平方米。这导致每平方米 265 瓦。Vensys 风力涡轮机的额定输出为 5.6 兆瓦，转子直径为 170 米，每平方米达到约 240 瓦。另一方面，光伏系统达到每平方米 100-200 瓦。2018 年，全球范围内太阳辐射的效率为 13.7%，与风力涡轮

photovoltaic systems reach 100-200 watts per square meter. The efficiency of solar radiation over the year, comparable as a criterion with the full-load hours of wind turbines, was 13.7% on a global scale in 2018. In Germany as a comparison, this percentage was 11.4% (calculated from the total photovoltaic energy and from the total photovoltaic power output in Germany, 2018).	机的满负荷小时相当。相比之下，德国的这一比例为 11.4%（根据德国 2018 年总光伏能量和总光伏发电量计算）。
Thesis 30: Compared to photovoltaic systems, wind turbines have both a 1.5 to 2 times higher area-related maximum output and a 1.5 to 2 times higher temporal efficiency (radiation efficiency/full load hours).	议题 30：与光伏系统相比，风力涡轮机的最大输出面积高出 1.5 至 2 倍，时间效率（辐射效率/满电小时）高出 1.5 至 2 倍。
If it weren't for the damn nuclear power plants that everyone supposedly doesn't want and still need for their daily electricity! The Isar 2 nuclear power plant near Munich, Germany, has an output of 1485 megawatts (see Wikipedia: Isar Nuclear Power Plant) and works almost continuously (96% of the time) with this output. The generated energy was in 2019 of 12 billion kilowatt hours. The Walney offshore wind farm employs 102 wind turbines, each with 3.6 megawatts, while an average of 2000 full-load hours per year,	如果不是那些该死的核电站，据说没有人想要，但仍然需要日常用电! 德国慕尼黑附近的伊萨尔 2 号核电站的输出功率为 1485 兆瓦（见维基百科：伊萨尔核电站），并且几乎连续（96%的时间）以这种输出功率工作。2019 年产生的能量为 120 亿千瓦时。沃尔尼海上风电场安装了 102 台风机，每台风机的功率为 3.6 兆瓦，而每年平均满电工作 2000 小时，产生的能量为 720 万千瓦时。

resulting in an energy of 7.2 million kilowatt hours.	
12 billion kilowatt hours with a nuclear power plant versus 7.2 million kilowatt hours with a wind farm? That's a pretty remarkable ratio of 1667 to 1!	120 亿千瓦时的核电站与 720 万千瓦时的风电场对比？这是一个相当了不起的比例，即 1667 比 1!
 Fig. 12 Offshore wind farm Walney, UK (Source: Reuters)	图 12 英国沃尔尼海上风电场（资料来源：路透社）
Thesis 31: The energy that the Isar 2 nuclear power plant near Munich provides per year (which is to be shut down in 2022) could be compensated with 1667 offshore wind turbines, which would be 16 offshore wind farms with 102 wind turbines each, similar to Walney off the coast of Great Britain.	议题 31：慕尼黑附近的伊萨尔 2 号核电站（拟于 2022 年关闭）每年提供的能源相当于 1667 台海上风力涡轮机提供的能源，即 16 个海上风电场，每个风电场配有 102 台风力涡轮机，类似于英国海岸的沃尔尼风电场。
Other comparisons are even sharper: "If the entire area of Germany were littered with wind farms 8 kilometers apart, the Federal Republic of Germany would be able to secure a quarter of its electrical energy," according to the daily German press. Journalists love sensation like theorists love simulation. But the reality is often quite different. In Germany, more than 21% of the	其他类比更加明显: "如果德国的整个地区都遍布着相距 8 公里的风力发电场，那么德意志联邦共和国四分之一的电能就有了保障," 根据德国日报的报道。记者们喜欢轰动效应，就像理论家喜欢模拟一样。但现实往往是完全不同的。在德国，2019 年超过 21%的电力由现有的 3 万台

electricity in 2019 was already generated by the existing 30,000 onshore wind turbines and the 1464 offshore wind turbines.	陆上风力涡轮机和 1464 台海上风力涡轮机提供。
Wind energy secured over 8% of the world's electrical energy demand in 2019 (according to the Global Wind Energy Council - GWEC). However, wind energy generated only 0.6% of the world's total primary energy consumption (statistical review of World Energy, 2017).	2019 年，世界上 8%以上的电源都由风能发电（全球风能理事会-GWEC 的数据显示）。然而，风能只占世界一次能源消费总量的 0.6%（《世界能源统计回顾》，2017）。
However, wind farms are increasing worldwide, and energy production without anthropogenic carbon dioxide emissions absolutely needs wind power, in addition to the other alternatives to fossil fuels.	然而，世界各地的风力发电场越来越多，除了是化石燃料的替代之外，若想利用没有人为二氧化碳排放的能源，风力发电必不可少。
Worldwide, according to Statista, the share of wind turbines in the production of electrical energy increased from 15.5% to 21.7% between 2015 and 2019.	根据 Statista 的数据，全球范围内，2015 年至 2019 年，风力涡轮机在电能生产中的份额从 15.5%增加到 21.7%。
In China, the world's largest emitter of carbon dioxide, with 28%, the expansion of wind energy is increasing significantly: The installed wind turbine capacity increased by 40% between 2015 and 2019, from 145 GW to 217 GW, in Germany, by 24% to over 61 GW in the same period. The USA had an installed wind turbine capacity of 113 GW	中国是世界上最大的二氧化碳排放国，风能发电占 28%，且仍在不断增加。2015 年至 2019 年，中国风力涡轮机装机容量从 145GW 增加到 217GW，增加了 40%；德国同期增加了 24%，增幅超过 61 吉瓦；2020 年，美国的风力涡轮机装机容量为 113GW，预计 2030 年将达到

in 2020, and 224 GW are expected for 2030, roughly as expected in China in 2020 [5].	224GW，与中国 2020 年的预期大致相同[5]。
The wind turbines really shoot out of the ground like mushrooms, even though they are so big and so heavy. Presented in 2020 by General Electric as the world's largest onshore plant, the "Cypress", with a maximum output of 5.5 megawatts, has a rotor diameter of 158 meters, the length of each of the 3 rotor blades is 77 meters. Such a rotor blade cannot be transported by a road train to the assembly site. For this aim special tractors are necessary. The **hub** height of this wind turbine can be between 101 and 161 meters. Such a colossus needs also an appropriate foundation: it weighs 3500 tons of concrete and steel, goes 4 meters into the earth and has a diameter of up to 30 meters. The wind turbine itself also weighs 3500 tons. That makes a total of 7000 tons.	风力涡轮机如雨后春笋一样拔地而起，尽管它们又大又重。2020 年，通用电气公司推出世界最大的陆上工厂"赛普拉斯"，最大输出功率为 5.5 兆瓦，转子直径为 158 米，3 个转子叶片的长度各为 77 米。这样的转子叶片无法用公路列车运送到装配现场。为此，需要特殊的拖拉机。这种风力涡轮机的**轮毂**高度在 101 到 161 米之间。这样一座庞然大物需要合适的基础：重达 3500 吨的混凝土和钢材组成，直径达 30 米，深入地下 4 米。风力涡轮机自重达 3500 吨，总重量达到 7000 吨。
Of course, this also has its price, one speaks of 1600 euros per kilowatt, which would be 8.8 million at 5.5 megawatts. But the costs don't count, we want to save the world!	当然，成本不低，有人说每千瓦 1600 欧元，如果是 5.5 兆瓦，就是 880 万欧元。但成本不重要，我们想拯救世界！
An interesting aspect is the rotor speed of a wind turbine in this power range, which, according to various sources, is between 4	有趣的是，这个功率范围内的风力涡轮机的转子速度，根据不同的来源，以及风速快慢，每分钟达到 4 到

and 13 revolutions per minute (rpm), depending on the wind speed.	13 转。
- At a rotor speed of 4 rpm, the speed of each of the 3 wings at its base, i.e. 2 meters after the center of the hub, is 3 kilometers per hour (km/h). At the wing tip, i.e. 79 meters from the center of the hub, the wing speed is already 120 km/h.	- 在转子速度为 4 转/分的情况下，3 个叶片中，每个叶片基部（即轮毂中心 2 米处）的速度为每小时 3 公里 (km/h)。在叶尖（即距轮毂中心 79 米处），叶片速度已经达到 120 公里/小时。
- If the rotor speed rises to 13 rpm the speed of each of the 3 wings will be 10 km/h at its base and 390 km/h at their tip. This tip speed can make any Formula 1 driver look pale!	如果转子速度上升到 13 转/分，3 个叶片中每一个叶片的底部速度都将是 10 公里/小时，叶尖速度是 390 公里/小时，任何一级方程式赛车手气馁面对这速度都会面露难色。
The displacement of the air **with the three long swords at 200-300 km/h** provokes not only noise **from lateral friction with the air** but also pressure waves due to **the frontal contact of the wing edges with the air in front of it:** This creates a local air compression, which causes a local increase in pressure. Such an increase in pressure propagates as a wave into the ambient air at the speed of sound (at 20°C it is 1235 km/h). The whole process develops as a result of pressure waves with highs and lows, this means as oscillations, with a frequency that depends on the rotor speed. A second source of pressure waves are the vibrations in each	**在 200-300 公里的时速下，风力发电机的三个叶片**使空气发生位移。它们与**空气的侧向摩擦**产生了噪音。此外，**叶片边缘与前方空气的前部接触**，又产生了压力波。这会造成局部的空气压缩，导致局部压力增加。这种压力增加以声速（在 20°C 下为 1235 公里/小时）以波的形式传播到周围空气中。整个过程是由压力波的波动发展而来，这意味着它是振荡的，其频率取决于转子的转速。压力波的第二个来源是每个叶片本身的振动，由于基座和尖端之间的压力载荷变化导致的。**根据叶片的旋转速度和位置不同，振动速度**分别

sword (wing) itself, due to the variable pressure load between base and tip, **at the speeds which, depending on the speed and position on the wing**, change from 2 to 120 km/h, respectively from 10 to 390 km/h. The third source of vibration is the mast itself, which carries the heavy **rotating wings** at a height of 161 meters. However, these oscillations have a different frequency **than that of the air pressure waves in front of the wing edges and then those of the wings over their length.** In this way, a wind turbine becomes a small (although so large) symphony orchestra. The people in the environment hear such vibrations, but they feel them as well.	从 2 到 120 公里/小时，再到 10 到 390 公里/小时不等。振动的第三个来源是风电塔本身，它承载着 161 米高且很重的**旋转叶片**。然而，这些振荡的频率不同体现在两方面。**一方面，与叶片边缘前部的空气压力波的频率不同。另一方面，与叶片长度方向的频率不同。**这样，风力涡轮机就成了一个小型的（尽管如此之大）交响乐团。环境中的人能听到这种振动，但他们也能感受到它们。
 Fig. 13 Onshore wind turbine of General Electric “Cypress”, currently (2020) the largest in the world (Source: General Electric)	图 13 目前（2020 年），通用电气的陆上风力涡轮机 “Cypress”，是世界上最大的风力涡轮机（来源：通用电气）。

The music has a natural basic tone for humans, but also for the animal world, which is defined by its frequency – 432 Hertz, or 25,920 sound wave peaks per minute. This is the resonance frequency of the cells in the bodies of humans and animals. The clear influence on the plants and trees is not discussed at this point.	音乐对人类来说有一种自然的基本音调，在动物世界亦是如此，这由它的频率决定——432 赫兹，即每分钟 25,920 个声波峰值。这是人类和动物体内细胞的共振频率。目前对植物和树木的明显影响，尚无探讨。
The musical frequency that generally reaches the souls of people is that of the bells of Tibet, those of Verdi, John Lennon or Enya. At an international conference on the frequency of the basic tone in music, in 1939, the hitherto common tone was increased from 432 Hertz to 440 Hertz and established as a universally applicable standard. This was a better fit for winning marches, which was very important for that time and its legislators. Otherwise, this increased basic tone rather irritate. Luciano Pavarotti himself has vehemently demanded that the old standard be reintroduced, unfortunately without success. It has also been proven in relevant studies that the basic tone at 432 Hertz creates a balance between the two hemispheres of a person’s brain. There are numerous musical works that are played on both fundamental tones – an experiment in	通常能够触动人们灵魂的音乐频率是西藏的钟声、威尔第、约翰·列侬或恩雅的音乐。1939 年，在一次关于音乐中基本音调频率的国际会议上，迄今为止通用音调从 432 赫兹提高到 440 赫兹，并被确立为普遍适用的标准。这更适合于赢得游行，这对那个时代及其立法者来说非常重要。否则，增加的基本音调会令人恼火。卢西亚诺帕瓦罗蒂本人曾强烈要求恢复旧标准，可惜没有成功。相关研究也证明，432 赫兹的基本音调在人的大脑两半球之间创造了平衡。有许多音乐作品都是在这两个基本音调演奏的--强烈建议本章的所有读者做这方面的实验。

this regard would be highly recommended for any reader of this chapter.	
Both the concentration periods and the creative phases can be stimulated with music – from heavy metal, hard rock and jazz to reggae, soul, country or opera. This depends both on the temperament and music education of the subject, as well as on his current mood and opportunity. With the vibrations of a wind turbine you can neither stimulate the concentration periods of a person nor his creative phases. Humans can acoustically perceive vibrations between 20 and 20,000 Hertz. The higher they get, the more they irritate and annoy. And if they fall below 60 Hertz or even below 20 Hertz? Then you don't hear them anymore. But you can feel them. And especially in such an infrasound range, the wind turbines emit a significant part of their vibrations, next to which people can hear.	音乐可以激发人们的专注力和创造性——重金属、硬摇滚、爵士乐、雷鬼音乐、灵魂乐、乡村音乐或歌剧都可以。选择哪种音乐，既取决于个人的气质和音乐教育背景，也取决于他当前的情绪状态和境遇。但用风力涡轮机的振动来激发一个人的专注力和创造性是不可能的。人类可以感知到 20 到 20,000 赫兹之间的声音振动。频率越高，就越会让人感到刺激和烦躁。如果频率低于 60 赫兹甚至 20 赫兹会发生什么呢？你会听不到声音，但是可以感觉到声音。特别是在这种次声范围内，风力涡轮机发出相当大一部分的振动声，人是可以听到的。
In medical studies, various influences of the low frequencies caused by wind turbines on humans have been found: On the one hand, they cause clear reductions in heart muscle strength (Gutenberg University of Mainz), on the other hand, the activation of various regions in the brain is responsible for stress	在医学研究中，已经发现风力涡轮机引起的低频对人类有各种影响：一方面，它们导致心肌力量的明显下降（美因茨古腾堡大学），另一方面，大脑中各种区域的激活是压力所致（汉堡埃彭多夫大学医疗中心）。

(University Medical Center Hamburg Eppendorf).	
The fact that birds and insects also fall victim to the rotor blades of wind turbines should not go unmentioned: The German Aerospace Center recently determined that 8,500 buzzards, 250,000 bats and 1,200 tons of insects were killed by the wind turbines in one year. Opponents, however, believe that the birds eat many more insects, about 400,000 tons in one year in Germany.	事实上，鸟类和昆虫也是风力涡轮机转子叶片的受害者，对此，应当引起重视。最近，德国航空航天中心测定，一年内有 8500 只秃鹰、25 万只蝙蝠和 1200 吨昆虫被风力涡轮机杀死。然而，反对者认为，鸟类吃的昆虫要多得多，在德国一年就吃大约 40 万吨。
Thesis 32: There will always be pros and cons in every respect, but especially in relationship with promising energy sources.	议题 32：世间万物皆有利弊，尤其是与有前景的能源相关的问题。
The church should still be left in the village, and please no giant windmill next to the church, that makes not only the pastor nervous.	教堂应仍留在村庄内，请勿在教堂旁建造巨大的风车，这不仅只会让牧师感到不安。
Humans are people, they don’t just react to the low frequencies. Nothing against it if wind turbines or wind farms are located on desolate fields, or in former open cut **mining fields**. But not instead of the Victory Column in Berlin or on the island of Mainau on Lake Constance. And also, not in the field of vision of Uncle Georg in Bavaria, of Monsieur Michel in Provence, or of Signor Giovanni in Tuscany: not in the front of their beautiful verandas with Alpes	人类之所以为人，他们不只是对低频有反应。如果风力涡轮机或风力发电场位于荒凉的田野上，或位于此前露天的**矿区**里，这无可厚非。但不是位于柏林的胜利柱或康斯坦茨湖上的迈瑙岛。也不是在巴伐利亚的乔治叔叔、普罗旺斯的米歇尔先生或托斯卡纳的乔瓦尼先生的视野中：不能在他们美丽的阳台前，那里坐落着美丽的阿尔卑斯山，有大片的花圃和一望无尽的橄榄树林。这

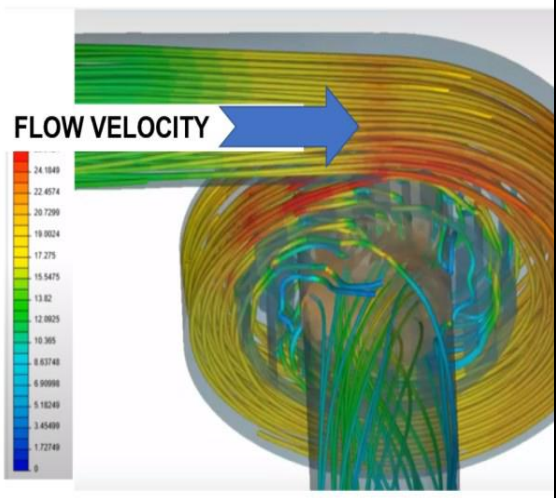
view, with large flower gardens or interminable olive groves. This may be subjective, but people love the beautiful, the harmonious, the aesthetic. A wind turbine is all that in itself: beautiful, harmoniously aesthetic. But not in the context of historical harmony and aesthetics, so the opinion of very, very many people.	样想可能是主观的，但人们都爱美丽、和谐且符合美学的事物。风力涡轮机本身就是美学：美丽又和谐。只不过不是在历史的和谐和美学的背景下，所以很多人都有意见。
Does anyone want to turn the Champs Elysées in Paris into Champs Moulinées?	有人想把巴黎的香榭丽舍大街变成香榭丽舍大街？
11.3 Hydropower	**水能**
Hydropower, just like wind power, is not the correct term in relating to what is expected of it: using the energy of wind or water to produce another form of energy, mainly electrical energy.	水能，如同风能，在涉及到对它的期望时，并非一个正确的术语：利用风或水的能量来产生另一种形式的能量，主要是电能。
But the people generally say wind turbine and hydroelectric power plant, so we leave them the names, we prefer to pay attention to the function: As with wind turbines, we need energy from hydropower plants in the form of work for the generators that have to produce electric energy. As with wind turbines, it makes more sense to talk about an instantaneous work flow (joules per second), that is nothing else than an instantaneous power (watts, kilowatts). Over a certain period of time, for example over a year, the outputs can be added	然而，通常情况下，人们都称为风机和水电站，所以随便吧，我们更关注其功能：和风轮机一样，我们需要水电站的能量，发电机必须生产电能的工作形式。与风机一样，谈论瞬时功流量（每秒焦耳）更有意义，这无异于瞬时功率（瓦特、千瓦）。在一定时期内，例如一年内，可以将任何一小时的输出功率加起来，这样就可以确定全年的能量（千瓦时，kWh）。

together at any hour, so that the energy throughout the year (kilowatt-hour, kWh) can then be determined.	
The instantaneous power in the turbine of a hydro-power plant can be determined similarly to that in the rotor of a wind turbine: The basic elements are the mass flow of the air or water and the specific energy of the respective medium: for the wind the specific kinetic energy, expressed by velocity, and in the case of water, the potential energy, represented by fall height and acceleration of the earth.	水力发电站涡轮机中的瞬时功率可以与风力涡轮机转子中的瞬时功率相似： 基本要素是空气或水的质量流量和各自介质的特定能量：对于风来说，是由速度表示的特定磁能，而对于水来说，是由地球的下降高度和加速度表示的势能。
The mass flow is given in the wind (air) as in the water, as the product of density, flow cross-section and flow velocity. But in the case of hydropower, there is a huge difference: Water has almost a thousand times the density of air, which is why the instantaneous power output of a wind turbine and that of a hydropower plant appear to be of different orders of magnitude:	风（空气）中的质量流量与水一样，是密度、流动截面和流速的乘积。但在水力发电的情况下，有一个巨大的差异：水的密度几乎是空气的一千倍，这就是为什么风力涡轮机的瞬时功率输出和水力发电站的瞬时功率输出似乎是不同的数量级：
The GE Cypress wind turbine has a maximum output of 5.3 megawatts. The three-gorge hydropower plant in China has a maximum output of 22,500 megawatts.	通用电气赛普拉斯风力涡轮机的最大输出功率为 5.3MW。中国的三峡水电站的最大输出功率为 22,500MW。

Just as long as people in their history used fire to generate energy in form of heat or work, so long another element, water, was used for same reason.	就像自古以来人们用火来发热、工作一样，人们用另一种元素——水，也是一样的目的。
The first watermills were used 5,000 years ago in China and Mesopotamia, according to chronicles. Later, in the VI century BC, a hydropower power plant was used in Jordan to crush stones for the construction of the Temple of Artemis. The first watermill to pro-duce electricity for house lighting was built in England in 1878. And a short time later, in 1895, the world's first large-scale hydropower plant for the production of alternating current was commissioned above Niagara Falls. The installed capacity reached after a few years more than 78 megawatts. In 1961, this hydroelectric power plant was replaced with a new one with a capacity of 2,400 megawatts.	据编年史记载，最早的水磨在 5000 年前就在中国和美索不达米亚使用。后来，在公元前六世纪，约旦的水力发电站被用来粉碎石头，以建造阿尔特弥斯神庙。1878 年，英国建造了第一座为房屋照明发电的水磨。不久之后，在 1895 年，世界上第一个用于生产交流电的大型水力发电站在尼亚加拉瀑布上方投入使用。几年后，装机容量达到 7800 多万千瓦。1961 年，这个水电站被一个新的容量为 2400 兆瓦的水电站所取代。
	图 14 尼亚加拉大瀑布，瀑布上面是罗伯特-摩西-尼亚加拉水电站，1961 年起，便成为了世界上第一个用于生产交流电的大型水电站。

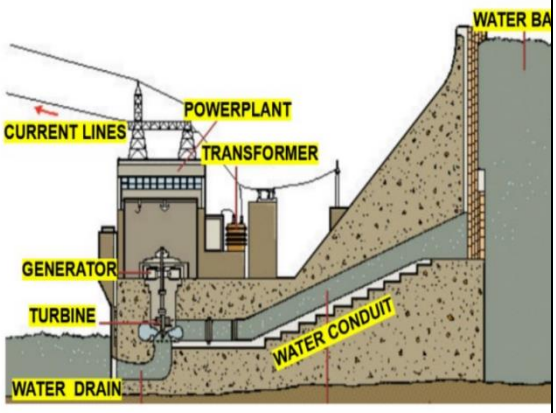
Fig. 14 The Niagara Falls, above it the Robert Moses Niagara hydropower plant, which replaces the world's first large-scale hydropower plant for the production of alternating current from 1961.	
Water, like air, has an energy that essentially consists of three components: internal energy expressed by temperature, pumping/potential energy expressed by pressure/drop height, and kinetic energy expressed by velocity. As long as the considered amount of water or air does not exchange energy in the form of heat and work with the environment, all its energy remains constant; however, the 3 components mentioned can exchange energy with each other during a process [1].	水和空气一样，能量基本上由三个部分组成：由温度表示的内能、由压力/下降高度表示的泵送/势能和由速度表示的动能。只要考虑到水或空气的数量不以热和功的形式与环境交换能量，其所有的能量就保持不变；然而，上述 3 个组成部分在一个过程中可以相互交换能量[1]。
For the qualitative evaluation of processes of all kinds, whether in wind turbines or in water turbines, the energy, including its three main components, is generally divided by the mass (kilograms) of the respective working medium, water or air. This is also advantageous because water, as well as air, does not appear in such applications as a solid, staying mass of a working media, but as a mass flow (kilograms per second). If you multiply now the mass flow by the mass-related energy,	为了对各种过程进行定性评估，无论是风轮机还是水轮机，能量，包括其三个主要组成部分，通常被除以各自工作介质（水或空气）的质量（公斤）。这也是有利的，因为水和空气在这种应用中不是作为工作介质的固体质量出现，而是作为质量流（公斤/秒）出现。如果你现在用质量流乘以与质量有关的能量，这将产生一个能量流，它不是别的，而是风车或水轮机中各自工作介质的瞬时功率。

this results in an energy stream, which is nothing else than the instantaneous power of the respective working medium in the windmill or in the water turbine.	
Starting from this point, a fascinating game begins for the water on the way to the turbine: Let's imagine that the water in such a system does not exchange any further energy with the environment, neither as heat nor as work. The water falls from the mountain because it has a potential energy at the given drop height. This potential energy is largely converted into speed (i.e. kinetic energy), a little pressure (potential energy) remains, depending on the conditions along the way. The internal energy, expressed by the temperature of the water, generally remains unaffected by the drop, apart from some friction, which is converted into heat, which is usually given to the environment, as a loss.	从这一点开始，水在通往涡轮机的路上开始了一个迷人的游戏： 让我们想象一下，在这样的系统中，水不会与环境交换任何更多的能量，既不像热能也不像功。水从山上落下，因为它在给定的落差高度上有一个势能。这种势能大部分转化为速度（即磁能），少量的压力（势能）仍然存在，取决于沿途的条件。内能通常以水温表示，不受温度下降的影响，除了一些摩擦会转化为热量，通常会在环境中消耗完。
Now the water from the mountain could fall directly into the turbine. However, it would be more advisable to first collect it in a basin, for hard times, when not enough water comes from the mountain. A certain drop height can then be constructed from the basin to the turbine. And henceforward the water reaches the turbine.	现在，山里的水可以直接落到涡轮机里。然而，更明智的做法是首先将其收集在一个盆地中，以便在困难时期，当山里的水不够用时，可以将其收集起来。然后从流域到涡轮机建造一定的落差高度。这样，水就会到达涡轮机。

There are several types of turbines, but we will consider in this chapter one of them (the Francis Turbine) that is most common in hydropower plants. This radial turbine works like a slingshot in which the process runs contrariwise:	涡轮机有几种类型，但在本章中，我们只考虑其中一种（混流式涡轮机），它在水电站中最常见。这种径向水轮机的工作方式就像一个弹弓，其运行过程是逆向的：
	Flow velocity:流速
Fig. 15 Flow path of water, from outside to inside, in a radial turbine (Francis Turbine)	图 15 为径向水轮机（混流式水轮机）中水从外到内的流动路径。
- In a slingshot, the stone is given a speed by the rotation, with which it then flies into the eye of the adversary. Within the turbine, the water enters the vortex from the outside at a high speed.	- 弹出弹弓时，旋转的石头有了一定速度，飞向对手的眼睛。然而在涡轮机中，水从外面高速进入漩涡。
- By flowing from the edge to the center and by diverting the water direction from horizontal to perpendicular, towards the exit of the turbine, the water is deprived of most of the speed (kinetic energy).	- 水流从边缘流向中心，水流方向从水平转向垂直，流向涡轮机的出口，从而使水流失去了大部分速度（动能）。
-This kinetic energy is converted in this manner into pressure (potential energy),	这种动能以这种方式转化为压力（势能），施加到转子叶片的侧翼。

which is applied to the flanks of the rotor blades. These blades are not fixed, but rotatable around an axis.	这些叶片不是固定的，而是可绕轴旋转的。
- And by the force generated on the blades surfaces this potential energy reaches the outside of the turbine, in form of a torque, at a corresponding rotational speed.	- 通过在叶片表面产生的力，这个势能以扭矩的形式和相应的速度，到达涡轮机的外部。
- And furthermore, the torque multiplied by rotational speed results in power. And the current generator flanged to the axle is pleased about this.	此外，扭矩乘以转速就会产生功率。目前与车轴相连的发电机对此很满意。
All right?	对吗？
Thesis 33: The power has the same roots for electrics, wind and water flow: an intensity (an electric current, but also a mass flow of air or water) and a potential (electrical voltage, height difference, pressure gradient, speed difference).	议题 33：电力、风和水流的根源是一样的：强度（电流，但也是空气或水的质量流）和电位（电压、高度差、压力梯度、速度差）。
Wasn’t that the case in electrotechnology: power is current multiplied by voltage?	在电工领域不就是这样吗：功率是电流乘以电压？
This is also how the hydropower plants are built, either with more emphasis on mass flow or more potential.	这也是水电站的建造方式，要么更强调质量流量，要么更强调电位。
A simple, concrete example shows both the relationships between mass flow and height difference, as well as the magnitude of the achievable power:	一个简单而具体的例子表明了质量流量和高度差之间的关系，以及可实现的功率的大小：
Ten buckets of water per second (that’s 100 liters, and with the water density of one	每秒 10 桶水（即 100 升，水的密度为每升 1 公斤，即 100 公斤）从 10

kilogram per liter just 100 kilograms) are poured from a height of 10 meters, through a pipe into a turbine. Multiplying the mass flow with the drop height and with the gravitational acceleration there appear no less than 10 kilowatts of power at the entrance in the turbine!	米高处倒下，通过管道进入涡轮机。将质量流量与水滴高度和重力加速度相乘，在涡轮机的入口处就会出现不少于 10 千瓦的功率！这就是所谓的水力！
Up to the electricity for the user, the 10 kilowatts are reduced by the efficiencies of the turbine, the gearbox, the generator and the transformer, but only to 8.5 kilo-watts. In comparison, the largest wind turbine in the world, “Cypress”, produces 0.265 kilowatts per square meter at maximum power. For the 8.5 kilowatts, as with the 100 liters of water that fall into the turbine per second from a height of 10 meters, a part of the rotor area of 32 m2 would be required. On the other hand, the comparison with the best solar cells, with 200 watts per m2, results in an area of 850 m2, which means around 30x30 meters!	到用户用电为止，这 10 千瓦的功率被涡轮机、齿轮箱、发电机和变压器的功效降低，但只达到 8.5 千瓦。相比之下，世界上最大的风力涡轮机“赛普拉斯”，在最大功率时每平方米产生 0.265 千瓦。为了达到 8.5 千瓦，就像每秒有 100 升水从 10 米的高度落入涡轮机一样，需要 32 平方米的部分转子面积。另一方面，与最好的光伏电池（每平方米 200 瓦）相比，其面积为 850 平方米，这意味着大约 30x30 米.
Hydropower plants are of different types:	水力发电站有不同的类型：
Run-of-river power plants are generally built in flowing waters, with a barrage at a weir, with the mass flow being the same at inflow and outflow. The potential due to a drop height is usually low, up to 15 meters, so the power is determined by the mass	河流发电站一般建在流动的水域中，在堰塞湖上设置拦河坝，流入和流出的质量流量相同。由于落差高度的潜力通常很低，最多只有 15 米，所以功率由质量流量决定，如尼亚加拉瀑布上方的水电站。

flow, as in the hydroelectric power plant above Niagara Falls.	
	Water basin: 流域 Powerplant:发动机 Current Lines:电线 Transformer: 变压器 Generator: 发电机 Turbine：涡轮机 Water Drain: 排水管 Water Conduit: 导水管
Fig. 16 Storage power plant (Source: Süwag Energie)	图 16 蓄能电站（资料来源：Süwag Energie）
Storage power plants get the water from basins (reservoirs or ponds). Between the basin, at a certain depth that provides a pressure potential, and the turbine, a diagonal water pipe with a defined head is built. So, this is a combination between the pressure potential at the inflow point and the speed potential in the line. Hydro-power plants with head heights of 25 to 400 meters cover base and medium loads of the required electrical energy and use Francis turbines in particular, as described above. At higher drop heights, the water potential increases accordingly, as does the pressure on the turbine blades. That's why in these cases not only Francis turbines, these reverse slingshots, but also Pelton turbines	流域（水库或池塘）中的水流到蓄能电站。在提供压力潜能一定深度的盆地和涡轮机之间，建立一个具有确定水头的斜向水管。因此，这是流入点的压力势和线路中的速度势之间的组合。水头高度为 25 至 400 米的水电站涵盖了所需电能的基本和中等负荷，特别是使用混流式水轮机，如上文所述。在更高的落差高度，水势相应增加，水轮机叶片上的压力也相应增加。这就是为什么在这些情况下，不仅弗朗西斯水轮机（这些反向弹弓），而且佩尔顿水轮机也在困难时被使用，这些是花环上的 "勺子"，水从上面落入。这通常涵盖了高峰负荷。

are used when it gets hard - these are “spoons” on a wreath into which the water falls from above. This often covers peak loads.	
The hydropower plant with the largest drop height in the world, 1,150 meters, is located in Naturns, South Tyrol. The plant has a power output of 180 megawatts	世界上落差最大的水电站，位于南蒂罗尔州的 Naturns，落差有 1150 米，该电站的发电量为 180MW。
Pumped storage plants prove a clever management of the electrical energy: They consist of two water basins at different heights, between which a down-up-pipe-system is built. When the near or wider area needs energy, the water flows from the full upper basin via turbines into the rather empty lower basin, thus driving the power generators and covering the peak loads. And so, at some point the water level in the upper pool is low and high in the lower pool. But at that time, mostly everyone, people like factories, enjoys their night’s rest. From there, the water is pumped up from the lower to the upper basin, **with the help of electricity from the grid, which almost no one needs at the time**. And that’s how it goes day and night.	抽水蓄能电站是电能管理的明智之举：它们由两个不同高度的水库组成，两者之间建有上下水管系统。当附近或更广泛地区需要能源时，水通过涡轮机从装满水的上水库流向几乎空的下水库，从而驱动发电机并满足高峰负荷。因此，在某个时候，上水库的水位较低而下水库的水位较高。然而，大多数人（如工厂的人）夜里正在休息，此时**几乎无人需要用电**。随后，**利用电网中的电力**，水泵将水从低处抽送到高处的水库。白天和晚上就这么运作的。
The world’s largest hydropower plant “Three Gorges”, with a reservoir length of 663 kilometers, built in China (completed in	世界上最大的水电站 “三峡水电站”，水库长 663 公里，建于中国（2008 年完工），额定输出功率为

2008), has a rated power output of 22,500 megawatts. The second largest plant, also in China, planned for 16,000 megawatts, will be completed in 2021. A total of a quarter of the world's hydropower capacity is installed in China. Brazil and Paraguay have jointly built a hydropower plant with 14,000 megawatts on the Rio Paraná, currently the third largest in the world.	22,500MW。世界第二大发电厂也在中国，计划发电量为 16,000MW，将于 2021 年建成。世界上总共有四分之一的混合动力发电能力安装在中国。巴西和巴拉圭在巴拉那河上联合建造了一座水电站，容量为14,000兆瓦，目前是世界第三大水电站。
The largest hydropower nation in Europe is Norway with 1500 hydropower plants (2019) that secure 93.5% of the country's electrical energy.	欧洲最大的水电国家是挪威，拥有1500 座水电站（2019 年），保证了该国 93.5%的电力能源。
Water provides about 17% of the world's electrical energy. Hydropower plants, on the other hand, have held first place in electricity generation from renewable energies for many years. In 2015, almost 70% of the world's clean electricity was generated from water, ahead of wind power at 15.5%. Photovoltaics managed just 5%. However, the economic, technical and ecological developments in the world are leading to tendencies that sometimes seem unexpected: In the period 2015-2019, the share of wind power in world electricity has steadily increased and reached almost 21%. Photovoltaics has moved in the same direction during this period, doubling to	水提供了大约 17%的世界电能。另一方面，水力发电站多年来一直在可再生能源发电方面占据首位。2015 年，世界上几乎 70%的清洁电力是由水产生的，超过了风力发电的 15.5%。而光伏发电仅占 5%。然而，随着世界经济、技术和生态带来了出乎意料的发展趋势，在 2015-2019 年期间，风力发电在世界电力中的份额稳步上升，达到近 21%。在此期间，光伏发电也朝着同样的方向发展，在 2019 年翻了一番，达到 10%以上。另一方面，水电的参与显示出大幅下降，从 70%降至约 58%。谁不喜欢水？

more than 10% in 2019. The participation of hydropower, on the other hand, shows a considerable decline from 70% to about 58%. Who doesn't like the water?	
The investment costs are very high and would only make such a system profitable if these costs were covered by electricity sales. But if the state is behind it for ecological reasons, like China, the situation is quite different. 3.15	投资成本非常高，只有在这些成本由电力销售覆盖的情况下，这样的系统才会有利润。但是，如果国家出于生态方面的原因而支持它，比如中国，情况就完全不同。
However, there is also a need for discussion and analysis about ecological reasons: Hydropower plants are atmosphere-friendly because the energy they produce does not cause carbon dioxide emissions, but they are not necessarily nature-friendly. Large basins are a huge intervention in the groundwater balance. As a result, the rivers are out of balance, flora and fauna are impaired. For the construction of dams, entire human places are often relocated.	然而，我们还需要就生态原因进行讨论和分析：水电站是环保的，因为它们产生的能源不会造成二氧化碳排放，但它们并不一定是生态友好的。大型水库会极大地破坏地下水平衡，从而导致河流失衡，动植物受到损害。为了建造大坝，整个社区常常需要搬迁。
Hydropower plants are also at risk of disasters, and have always been:	水电站也面临着灾难风险，而且一直如此：
In China, near Nanking, in 516 the largest dam of the time (the dam was 48 meters high and 4500 meters long, the basin had 6700 km2) was destroyed by flooding, there were 10,000 dead people. Admittedly, this	在中国南京附近，516 年发生的一次洪水冲毁了当时最大的大坝（大坝高 48 米，长 4500 米，流域面积 6700 平方公里），造成 1 万人死亡。当然，这座大坝的建造目的并非发电，而是用于淹没敌军。

dam was not intended for power generation, but for flooding enemy armies.	
The dam wall of the largest dam and equal drinking water reservoir of the Romans, built in the time of Nero (54-68 AD), not far from Rome, collapsed in 1305.	在罗马皇帝尼禄（公元 54-68 年在位）统治时期，在离罗马不远的地方建造了罗马最大的大坝，同时也是一座饮用水库。然而，在 1305 年，大坝的坝体坍塌了。
In France, near Frejus, a dam was built in 1954, creating a reservoir for water supply and irrigation. It broke in 1959 as a result of a tidal wave. 432 people were killed.	在法国弗雷儒斯附近，1954 年建造了一座水库，用于供水和灌溉。然而，1959 年，由于一次潮汐波，大坝破裂，造成 432 人死亡。
In California, 3 dams broke as a result of an earthquake in 1971.	1971 年，加利福尼亚州有 3 座大坝因地震而破裂。
The Banqiao Dam in China, built in the late 1950s, had a capacity of nearly 50 million cubic meters of water. As a result of a typhoon, there was a huge flood, which could not be stopped by the lock gates. The rupture of the Banqiao Dam cascaded the rupture of another 62 dams. The water waves were several meters high and flowed into the lowlands at almost 50 km/h. Numerous villages were flooded so quickly that there was no time left for the evacuation of people and animals remained. Over a million people were trapped by the water for days, unreachable for any disaster relief. At least 26,000 people died as a result of the immediate tidal waves, while another	建于 20 世纪 50 年代末期的中国板桥大坝蓄水量近 5000 万立方米。由于台风引发了巨大洪水，水闸无法阻挡洪水，板桥大坝溃坝后导致另外 62 座大坝接连溃坝。数米高的水波以近 50 公里的时速涌向低洼地区，众多村庄迅速被淹没，人们和动物来不及撤离。超过百万人被困水中数日，救援队伍无法抵达。水灾造成的直接死亡人数至少为 2.6 万人，另有 14.5 万人死于饥饿和疾病[6]。

145,000 died of starvation and epidemics [6].	
Thesis 34: For a total power output considered, a number of micro-hydropower plants can be more ecologically compatible, less dangerous and more cost-effective than a single, large hydropower plant with a large dam, with a large reservoir and with a large head of fall.	论点 34：对于相同的总功率输出，多个微型水电站可能比单个大型水电站更生态友好、更安全、成本效益更高。大型水电站通常配有大型水坝、大型水库和较大的落差。
Recently, micro hydropower plants have been developed for river sites with low hydropower potential [7]. The small mobile power plants work without accumulating water. Only a water drop height of at least 2.5 meters is necessary, with a water width of five meters and a flow speed of over 5 km/h. For this purpose, new horizontal waterwheel variants are being developed. The micro-hydropower plants can also be set up as a fleet, which opens up promising paths!	最近，科研人员针对水力发电潜力较低的河流区域，成功研发出微型水电站[7]。这种小型移动电站无需蓄水即可工作，仅需满足水降高度至少 2.5 米、水宽 5 米、流速超过 5 千米/小时的条件。为此，我们也在积极开发新型水平水车。微型水力发电厂还可组建为机组，前景十分广阔！

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