# We-Energy Game

# Manual

**It's all in the game**

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## SAMENVATTING

# 1. INTRODUCTIE

De We-Energy Game is ontwikkeld aan de Hanzehogeschool Groningen bij het Centre of Expertise - Energy (CoE-E ) en haar innovatiewerkplaats EnTranCe (zie http://en-tran-ce.org/). Sinds de oprichting van EnTranCe en het CoE-E is regelmatig de vraag naar voren gekomen wat duurzaamheid nu precies is en welke inspanningen echt nodig zijn om de opwarming van de aarde een halt toe te roepen. Duurzaamheid ziet er voor elke stakeholder anders uit. Om een regio (dorp, stad, provincie, land) duurzaam te krijgen, moeten beelden van verschillende stakeholders uitgewisseld worden. Ten eerste om gezamenlijk tot een breed gedragen definitie te komen en daarmee overeenstemming te bereiken in wat de opgave betekent. Ten tweede om het perspectief te leren kennen van alle stakeholders, wat inhoudt dat men de verschillende belangen leert kennen en de risico's en kansen die men vanuit verschillende posities ziet. Omdat het doorgaans lastig is het eigen perspectief lost te laten, vooral als de belangen groot zijn, hebben we het We-Energy Game ontwikkeld. Het spel is zeer geschikt om op lokaal niveau het gesprek over duurzaamheid te starten. De eerste keer dat een ruwe versie van het spel gespeeld werd, was in het huis der provinciën in Brussel, België. De doelen in de vorm van discussie, dialoog en het zoeken naar consensus aan de hand van de complexe keuzes van de energietransitie, kwamen direct aan het licht en gaf reeds een indruk van de kracht van de We-Energy Game. Vanaf de eerste spelversie is het spel uitgebreid en geprofessionaliseerd en is het in meer dan 150 sessies gespeeld. Alle drie Noordelijke provincies, meer dan 50 gemeenten, netbeheerders, bedrijven, adviesbureaus en verschillende energie coöperaties hebben het spel inmiddels gespeeld. De game komt het best tot zijn recht als het als bordspel wordt gespeeld, maar er is ook een digitale versie. Tijdens het bordspel nemen 6-8 personen plaats aan een tafel waar minimaal een A0 poster op kan liggen. Grotere groepen per spel zijn mogelijk, maar dan dient een aantal deelnemers samen een rol op zich te nemen. Bij voorkeur bestaat het speelveld (zie afbeelding 1) uit een op maat gemaakte kaart? van de gemeente waar het spel wordt gespeeld, zodat er een realistisch beeld ontstaat die de complexiteit van de energietransitie in het gebied waar het plaats moet vinden, duidelijk maakt. De kracht van het spel is dat er alleen door dialoog en consensus een klimaat-neutrale gemeente mogelijk is.
Voor een discussie omtrent de lokale energie-opwek tussen een gemeente en haar burgers is een groep tussen de 20-40 deelnemers ideaal, waarbij het mogelijk is het spel met meer of minder deelnemers te spelen. De hoeveelheid spelbegeleiders is afhankelijk van de groepsgrootte. Er is in ieder geval één hoofdbegeleider aanwezig voor de introductie en uitleg van het spel en om de discussie achteraf te leiden. Deze zal tijdens het spelen van het spel, samen met de tafelbegeleiders het spel begeleiden. Per twee speeltafels van 6-8 personen zal er een begeleider aanwezig zijn. Dit zorgt ervoor dat de deelnemers ook tijdens het spelen van het spel hun vragen kunnen stellen. De begeleiders spelen een faciliterende rol en zullen zich verder niet met het spel bemoeien, om zodoende de spelers volop de gelegenheid te geven om met elkaar in gesprek te gaan. De keuzes in het spel zijn realistische keuzes, waarbij scores in het spel voor wat betreft sentiment, balans en opbrengsten gebaseerd zijn op de meest recente gegevens. De deelnemers aan het spel zijn veelal bestuurders, bewoners en vertegenwoordigers van belangengroeperingen. Juist deze mix van soms tegengestelde belangen, maakt het spel realistisch. Daardoor biedt We-Energy Game inzichten in de complexiteit en omvang van de opgave, alsmede dat het een startpunt is van de invulling van de energietransitie en de totstandkoming van de duurzame samenleving.

## 1.1. Behaalde resultaten

De We-Energy Game is grootschalig ingezet om het bewustzijn van de grootsheid en de complexiteit van de energietransitie te vergroten. In meer dan 150 sessies hebben bestuurders, ambtenaren en burgers inzichten verkregen door het spel te spelen en is vaak gestart met acties en initiatieven. Deze acties kunnen bestaan uit het stimuleren van lokale energiecoöperaties, het mogelijk maken van zonneweides en het zoeken naar geschikte locaties voor biogas, geothermieprojecten en/of windmolens. Zo heeft de Provincie Groningen ervoor gekozen de We-Energy Game te gebruiken om in contact te komen met haar bewoners en zo informatie over de meningen van hen te verzamelen. Deze informatie uit de game wordt gebruikt om het beleid van de provincie op het gebied van de energietransitie mede te bepalen. De provincie Drenthe heeft een digitale versie van We-Energy Game met ons en een derde partij ontwikkeld. Deze digitale versie kan thuis worden gespeeld. De We-Energy Game is inmiddels dusdanig succesvol dat we bezig zijn met de verdere ontwikkelingen, zoals de doorontwikkeling van de digitale versie en het ontwikkelen van een planningstool waarmee de daadwerkelijke gegevens toegevoegd worden, alsmede een monitor van de behaalde resultaten. De kracht van de We-Energy Game ligt echter niet in de game zelf, maar in het versnellen van de discussie en het debat rondom de stappen die genomen dienen te worden richting een duurzame samenleving.

## 1.2. Opbouw van de game

Tijdens de We-Energy game is het de bedoeling dat de deelnemers een dorp of stad elektrisch energieneutraal maken. Daarvoor krijgen zij verschillende rollen toebedeeld. Deze rollen staan elk voor een stakeholder uit de omgeving die te maken heeft met de energietransitie (productie, wetgeving, mensen, planeet, winst, balans/netbeheerder). Vervolgens moeten de deelnemers hun eigen lokale omgeving invullen met energiebronnen. Deze bronnen hebben elk een andere score. Zo zijn de meeste inwoners tegen de komst van grote windturbines in hun directe omgeving zijn. Voor het energieneutraal maken zijn deze turbines echter een belangrijk instrument. Dit soort vraagstukken, samen met het vraagstuk van de lokale ruimtelijke invulling, worden bespreekbaar gemaakt tijdens het spelen van het spel. De discussie en dialoog die hierdoor ontstaat is het grootste doel van het spel. Het geeft de deelnemers meer kennis over de energietransitie en zorgt ervoor dat zij inzichten verkrijgen in deze complexe opgave.

## 1.3. Verloop van het spel

De deelnemers krijgen via de organiserende gemeente een link naar een online enquête die gebruikt zal worden voor de indeling van de tafels en voor de centrale presentaties. De link, opgenomen in de uitnodiging voor deelname aan het spel, gecombineerd met informatie over het spel zal minimaal een week voorafgaand aan het spel worden verstuurd, zodat we de gegevens kunnen gebruiken in de presentatie en de indeling van de tafels[1]. Bij aanvang van het spel zal er eerst een presentatie gegeven worden over de Energietransitie, de mogelijkheden en onmogelijkheden en de meest recente stand van zaken waaronder gegevens van Energieopwek.nl, specifiek voor de gemeente/regio waar het spel wordt gespeeld. Natuurlijk worden de uitkomsten van de enquête onder de deelnemers gepresenteerd (15 minuten). Daarna krijgen de deelnemers uitleg over het spel (5 minuten). Tijdens deze uitleg ligt de nadruk op samenwerking tussen de verschillende stakeholders. Om de deelnemers te tonen hoe belangrijk deze samenwerking is, spelen ze de eerste ronde van het spel juist individueel. Dit houdt in dat elke deelnemer gedurende de eerste ronde op zoek gaat naar de energiebron die voor zijn rol het beste uitpakt, zonder rekening te houden met de andere rollen. Waaruit duidelijk wordt dat samenwerking vereist is. Vanaf dat moment is samenwerking nodig en moeten alle rollen een minimale score halen om de gemeente elektrisch energieneutraal te maken (30 minuten). Als ze klaar zijn met het eerste deel van de opgave (elektriciteit) krijgen de deelnemers de opdracht om ook de warmte- en transportvraag energieneutraal te maken. Er worden dan nieuwe kaarten geïntroduceerd en de spelopgave wordt daarmee natuurlijk complexer (45 minuten).
De kaart van de eigen gemeente is uitgangspunt van het spel. Zo wordt stapsgewijs een realistische planning gerealiseerd van de totale energievraag van de eigen gemeente gemaakt. Daarmee kan een planning worden gemaakt en kan gezamenlijk een breed gedragen invulling van deze opgave worden gemaakt. Na deze tweede ronde is het tijd om de nodige informatie op te halen. Hiervoor wordt een discussie gevoerd met de deelnemers over de, voor hen, meest geschikte oplossing. Als deze discussie niet natuurlijk ontstaat, vragen wij de voorzitter van elke tafel om in één minuut hun gekozen oplossing te pitchen. Aan de hand van de verschillende pitches wordt de discussie gestart. Tijdens het spel worden er door de begeleiders foto's genomen, die gebruikt worden tijdens de presentatie in de slotdiscussie, alsmede dat de daadwerkelijke resultaten van de verschillende tafels worden gepresenteerd (45 minuten).
Een sessie, zoals hierboven geschetst, duurt ongeveer twee uur inclusief de uitleg van het spel. Het laatste deel wordt besteed aan de centrale discussie, waarin de opties voor nader stappen en acties die voortvloeien uit het spel en de verkregen inzichten. De Hanzehogeschool kan helpen en faciliteren zijn in deze verdere stappen.

[1] Volgens de nieuwe AVG-standaard

## 1.4. Verdere ontwikkelingen van het spel

Vanaf het eerste gebruik is het spel constant in ontwikkeling geweest. In de beginfase lag de focus voornamelijk in het optimaliseren van de bewustwordingskant voor de speler wat resulteert in het spel beschreven in dit document. Daarnaast heeft de focus voor verdere ontwikkeling zich ook verplaats naar planning van duurzame energy in lokale gebieden. Hetzelfde spel kan hiervoor gebruikt maar dan wordt er gewerkt met werkelijke vraag en productiegegevens. Om de vraag gegevens van een gemeente te achterhalen wordt hiervoor eerst een QuickScan uitgevoerd (kijkend allereerst naar elektriciteit). Daarnaast zijn de productiegegevens van de originele duurzame energy bronnen in de we-energy game per hectare gegeven. Daarop gebaseerd kan de kaart van het spel (zie hieronder) worden ingevuld met oppervlakten benodigd om de elektriciteitsvraag van een gemeente te produceren met de bronnen gebruikt in de originele we-energy game.  Een bepaalde richting van vervolgonderzoek aan het CoE-E richt zich op de werkelijke productie van meerdere energiebronnen voor zowel elektriciteit, warmte, transport en of een combinatie hiervan; kijkend niet alleen naar de productie van een bron maar ook naar de impacts op het milieu, de kosten en de impact op het energiesysteem. Aanvullend worden hier technieken voor energieopslag aan toe gevoegd. Hiervoor zal een model morden samengesteld die uitkomsten genereerd voor Productie, Planeet, Winst en Balans ook wel de We-Energy Tool genoemd. De Tool kan in samenwerking met de We-Energy Game een verdere uitbreiding worden voor het plannen van duurzame energie.

## 1.5. Inzet van We-Energy game in de energietransitie

De We-Energy game is ontwikkeld om inzichten te krijgen in de complexiteit van de energietransitie. De kracht van het spel ligt in de bewustwording van de deelnemers van de grote opgave en noodzaak om iedereen hierin te betrekken. Naast de We-Energy game biedt de Hanzehogeschool verdere instrumenten aan om gemeenten, provincies en anderen te helpen in het realiseren van de klimaatdoelen. Zo is er op de Hanze een pakket ontwikkeld dat gebruikt kan worden door individuele bewoners om inzichten te krijgen in het persoonlijke energieverbruik. Met speur de energieslurper, check je warmtelek en is je CV oké kan een huishouden het verbruik van de gebruikte apparatuur vaststellen en vergelijken met anderen, kan de isolatiebehoefte van een huis worden vastgesteld en kan een check van de centrale verwarmingsinstallatie plaatsvinden. Gekoppeld aan collectieve inkoop van zonnepanelen en warmtepompen (bijvoorbeeld via de lokale energiecoöperatie kan dit al een belangrijke eerste stap zijn om bijdrage te leveren aan de energietransitie. Dit soort projecten zijn of worden uitgevoerd in Buurkracht (met buren), Bedrijfkracht (met collega's/ teams in bedrijven). De provincie Drenthe heeft de Hanzehogeschool subsidie gegeven om binnen 2 jaar 10.000 huishoudens uit de provincie te betrekken met deze energiebewustwording campagne. Wij zien We-Energy game als een start van een bewustwordingscampagne voor bewoners en bestuurders. Het lectoraat Communication, Behaviour & the Sustainable Society van het CoE-E van de Hanzehogeschool heeft veel expertise in huis om de energietransitie en de totstandkoming van de duurzame samenleving mede vorm te geven door een veelheid van mogelijke acties, onderzoek en inzet van studenten die eventueel in vervolgprojecten kunnen worden ingezet. Ons doel is niet commercieel, maar uit een betrokkenheid en uit een uitdaging die de maatschappij aan ons heeft gegeven. Wij willen onze hulp, expertise en inzichten aanbieden aan alle deelnemers van het spel om zodoende een bijdrage te leveren aan de grote klimaatuitdagingen. Na ieder spel maken wij een deelrapport maken waarin uitdagingen en de uitkomsten van het spel worden gekoppeld aan de mogelijke maatregelen en acties. De provincie en alle deelnemers zullen uitgenodigd worden voor een eindsessie, waarin we de verhalen, inspiraties en collectieve inspanningen zullen bundelen.

## 2. THE GAME IN BRIEF

The game is a representation of how energy transition affects different important sectors of a community (Such as, people, profit, balance, production and planet). The players take the role of one of these important sectors and try to make their village or city energy neutral. The game consists of two rounds. The first round takes place in a village and the second round takes place in a city. The players for both rounds need to reach their individual and production score before the time ends. To be able to achieve their goals, the players must place energy sources cards on the map and collaborate with each other. The scores of each card are based on realistic impacts of each energy source. The scores refer to the amount of energy, emissions and impact.

### 2.1. Object of the game

Make the participants, through gaming and discussion, more sensitive and aware. Regarding the importance of sustainable energy and how the different roles are involved in the process.

### 2.2. Roles in the game

The players take the role of an important player within a community and try to reach their individual goal, by placing energy cards on the map. The players can choose which role they want from the following sectors:

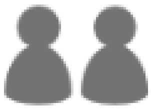
| | |
|---|---|
|  |  |
| **Production/Chairman**<br>The Chairman is the person responsible for the production of electricity. The chairman needs to produce enough energy to provide all households in the area with sustainable electricity. | **People**<br>The player with the people role represents the citizens of the chosen area. These citizens want sustainable energy but prefer some types of energy sources above others |
|  |  |
| **Planet**<br>The player who chose to represent the planet needs to provide a clean and sustainable energy solution like windmills and solar PV fields. | **Profit**<br>The player who represents the profit tries to make as much money with the different energy sources as possible. |
|  | |
| **Balance**<br>Often forgotten but the network operator must also work with the chosen solutions. He prefers solutions with a stable production like any form of biomass | **Permits** |

Fig. 2.1. Main roles (Stakeholders) in the game

### 2.3. Energy source cards

Each card represents a different type of energy source that can be used to produce electricity, warmth and other things. The players receive points by placing energy source cards on the map. For example, the Planet player prefers to place a “Solar PV field” card rather than a “Battery” card on the map because it gives him more positive points. The energy sources that are mentioned in the game are:

1) Solar PV field

2) Solar PV on rooftop
3) Large wind turbine
4) Biomass waste CHP
5) Biomass remains CHP
6) Biogas maize CHP
7) Battery
8) Efficiency

Efficiency card: By playing this card, the demand of the final scores are reduced by 10%. For example, during the second round, Planet player placed an Efficiency card on the map and received 10 points for his role, also, the demand of all players' final scores are reduced by 10%, from 500 points went to 450 points.

## 2.4. Scores of the energy sources per role

Each energy source card has different scores for each role. For example, "Energy crops AD" card gives 15 points for production, 10 points for permits, -5 points for people, -10 points for planet, 10 points for profit and 20 points for balance. NOTE! Each card can give maximum 25 points and minimum -25 points The Chairman does not keep track of his individual goal because he has a different role in the game. The Chairman player makes sure that the production and individual scores are reached before the time ends. For example, giving suggestions, reminding the current standings of the scores, etc. NOTE! All roles must achieve production score

## 2.5. Placing energy source cards

Each card can be placed on specific areas on the map. Only on areas suited for specific cards. For example, wind turbine cards can be placed on the field, but they cannot be placed on the roofs of the houses. NOTE! Efficiency, Battery and Combined Heat Power cards can be placed everywhere inside or outside of the map

## 2.6. Playing the game

### *2.6.1. Goal of the game*

- For both map, all players much achieve their individual scores
- For both map, all players much achieve production scores

### *2.6.2. Sequence of the play*

The players are free to discuss and try out of the possibilities for achieving the production and their individual scores, by placing energy source cards on the map. The game is divided in 2 maps

Table 2.1. The two main fases in the game

| **First map - Ten Boer** | **Second map – Groningen** |
|---|---|
| For this game, the village map is going to be used. The players have 10 minutes to reach 20 points for production and 20 points for their roles | For this game, the city map is going to be used The players have 10 minutes to reach 80 points for production and 80 points for their roles |

### *2.6.3. Combinations*

It is possible to place 2 different energy source cards one above the other. The possible combinations are:
- Big wind turbines cards with Biomass remains cards
- Solar PV rooftops cards with Organic waste cards

### *2.6.4. Ending*

Both rounds end when the time is over. After the second round, the participants can discuss what did they learned and observed from the game.

### 2.6.5. *DISCLAIMER*

The board game is based on the PhD research of Frank Pierie, a researcher at the Hanze University of Applied Sciences, Groningen. All the information used, had the intent to make the game as possible interesting, interactive and close to reality.

## 2.7. Componants in the game

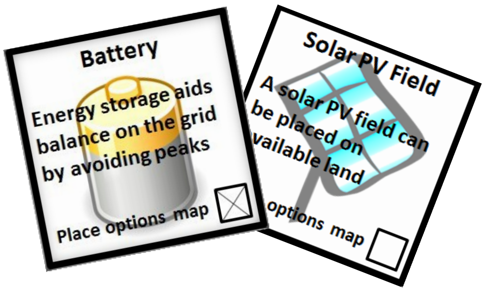
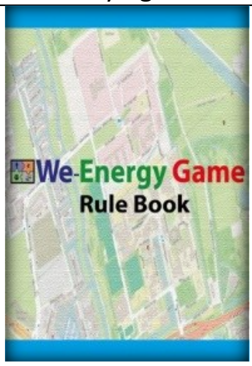
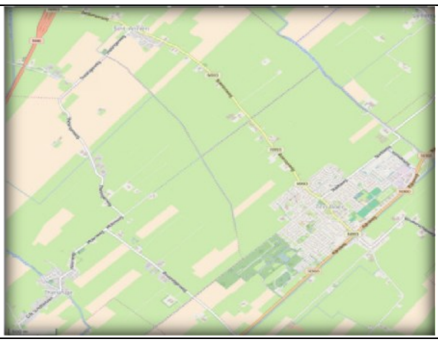
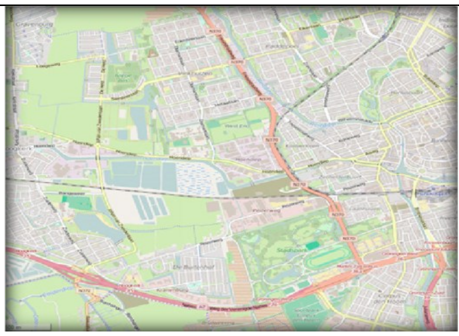
| | |
|---|---|
|   |   |
| 72 Playing cards | 6 role cards |
|   |  |
| 1 Manual | 1 board Game |
|  |  |
| 1 Village map | 1 City map |
| | |
| 2 Additional demand cards | Desission cards |
| | |

Fig. 2.2. Elements in the We-Energy Game

# 3. AWARENESS REGARDING THE NEED FOR AN ENERGY TRANSITOIN

Energy transition can be described as the transformation from a system based on fossil fuels to a system based on renewable energy sources and much less $CO_2$ emissions. This is a long-term structural change of the entire energy system. Why would we need such a transition?
There are three main drivers for the energy transition:

- **Climate change:** Rising levels of greenhouse gas emissions cause the global climate to change. Climate change will have a massive impact on physical, biological and human systems.
- **Depletion of resources:** Fossil fuels are a *finite resource*, which means that their supply will end one day. A good example of such depletion is the Groningen gas field: about 75% of the gas has already been extracted since the sixties. When fossil fuel reserves are depleted we have to move to alternatives.
- **Security of supply:** Modern societies are heavily dependent on energy. A secure energy supply is of high economic interest. Being dependent on foreign nations for the supply of energy or resources, countries are exposed to price increases and geopolitical conflict.

This chapter discusses these three drivers for the energy transition. The mechanism of climate change and its relationship with fossil fuel consumption is discussed first. The second paragraph discusses the topic of resource depletion and the third looks deeper into the factors influencing the security of energy supply.

## 3.1. Climate change

Climate change in itself is not a new phenomenon. For millions of years the climate has been changing. Ice ages are alternated with warmer periods. An example is the Medieval warm period in the North Atlantic that lasted from the year 950 to 1250 AD. It was followed by a cooler period (from the 16th to the 18th Century), the Little Ice Age. Fluctuations in the climate are driven by changes in the variations in the Earth's orbit (Milankovic cycle), variations in the sun's activity, volcanic activity, etc. Some of the changes are cyclic (such as the Milankovic cycle), which means that the fluctuations take place with repeating cycles of several thousands of years, which are also predictable to some extent. What is worrisome about the climate change taking place right now, is the fact that it is taking place rapidly, and that there is human influence on natural cycles. Therefore, we also refer to the current climate change as 'anthropogenic climate change' (anthropogenic meaning "originating from human activity"). There is increasing scientific evidence for anthropogenic climate change. The International Panel on Climate Change (IPCC), a global organization that assesses climate change, plays an important role in collecting scientific evidence. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge on climate change and its potential environmental and socio-economic impacts.

## 3.2. Greenhouse gas emissions and the enhanced greenhouse effect

Anthropogenic climate change is caused by increased levels of greenhouse gas (GHG) emissions. Greenhouse gas emissions cause the greenhouse effect. This is a natural phenomenon that enables the atmosphere to capture heat from solar radiation. Without the greenhouse effect there wouldn't be life on Earth because the temperature would be far too low. When the natural balance of GHG emissions is disrupted, the functioning of the greenhouse effect is disrupted. With rising levels of GHG emissions, we now speak of the enhanced greenhouse effect. Light from the sun passes through the atmosphere and is absorbed by the Earth's surface, warming it. Greenhouse gases, like carbon dioxide, act like a blanket, trapping heat near the surface and raising the temperature. Note that this a natural process that keeps our planet a perfect place to live on. Without this thin layer of greenhouse gasses in our atmosphere, life on earth would be impossible. Now, when *additional* greenhouse gasses are released into the atmosphere by burning fossil fuels, this "blanket" grows thicker and traps more heat. As can be seen on the right side of figure 2, this leads to more re-emitted heat toward our planet and less heat released back into space. The sum of all this: an increase in the average global temperature.

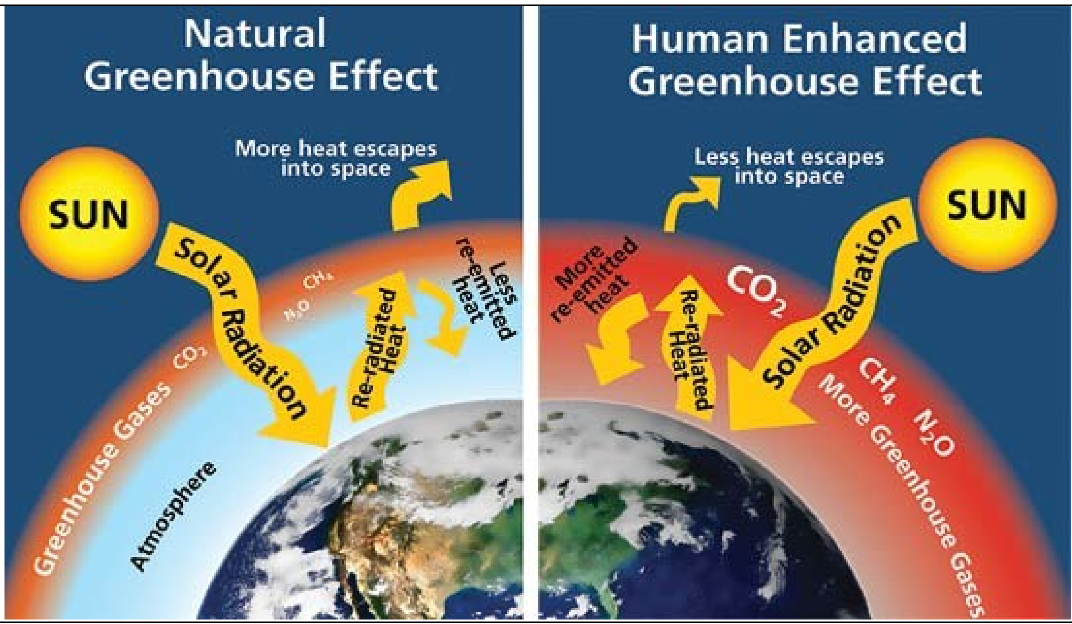



Figure 3.1. The greenhouse effect [2].

## 3.3. It's all about carbon dioxide emissions

Ever since the industrial revolution in the 19th century our society has been using more machines and equipment. Up until today fossil fuels are mostly used to drive these machines. When burning fossil fuels to generate the required energy, carbon dioxide is emitted into the atmosphere. Figure 3 shows a rise of carbon dioxide in our atmosphere for the last 1100 years. The year 1769 marked on the graph is the year in which James Watt patented his steam engine. While the first practical steam engine was invented in 1698, Watt's more efficient steam engine really got the Industrial Revolution going [4].

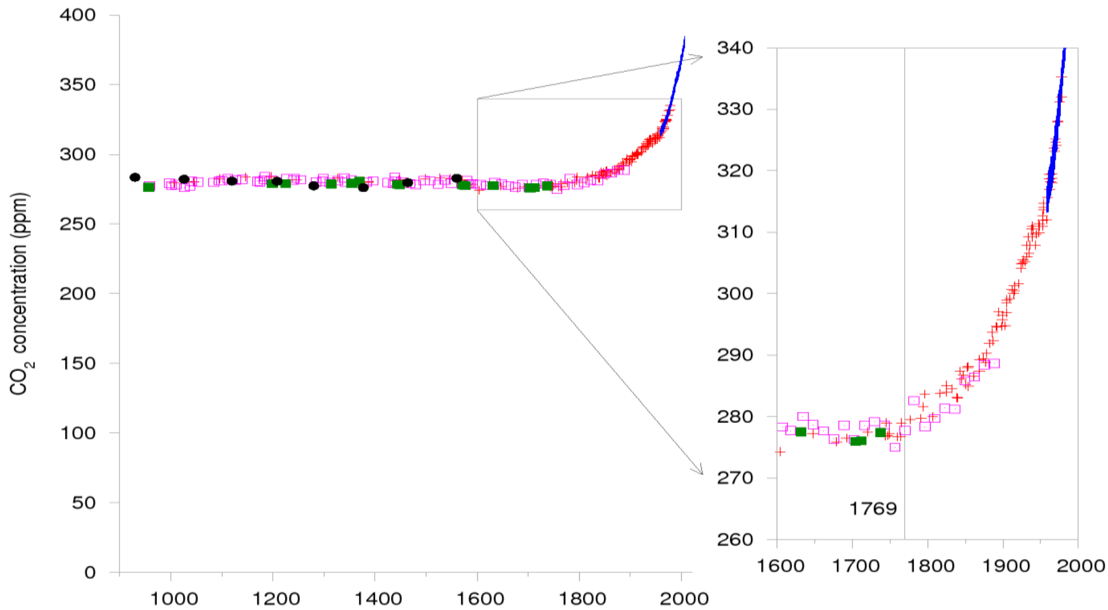



Figure 3.2. Carbon dioxide concentrations (in parts per million) for the last 1100 years. [4]

Carbon dioxide emissions are still increasing because the world population is increasing (and thereby also the energy consumption) as well as the wealth in certain regions. Especially in parts of Asia living standards are improving, which also leads to a higher energy consumption in those societies. It is therefore important that we decrease the world's energy consumption and use energy more efficiently. In conclusion, anthropogenic greenhouse gas emissions has increased since the pre-industrial era, driven largely by economic and population growth and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years [1].

### 3.4. Climate Change: the effect of rising $CO_2$ emissions on natural systems

The rise of GHG emissions causes climate change. What effects do rising emissions have on natural systems exactly? The most important negative consequences are:

- **Global warming:** Both the atmosphere and oceans will continue to warm and because the global temperature is rising, the ice on the poles will melt, which will cause the sea levels to rise. For coastal areas such as the Netherlands, which are below or just above sea level, this will have serious consequences.
- **Extreme weather:** The rise in temperature is not the only effect of climate change. There is an increase in extreme weather patterns events. Changes in extreme weather and climate events have been observed since around 1950 ([1]). In the future there will be more and heavier storms, extreme rainfall, an increase in warm and cold temperature extremes and there will be larger and longer periods of heat and drought. Hence more wildfires and the endangerment of food production in agricultural areas.
- **Changing ecosystems:** Species cannot keep up with all the sudden changes in natural habitats. Some species will to become extinct while others will adapt or migrate. Ecosystems will be effected by climate change.

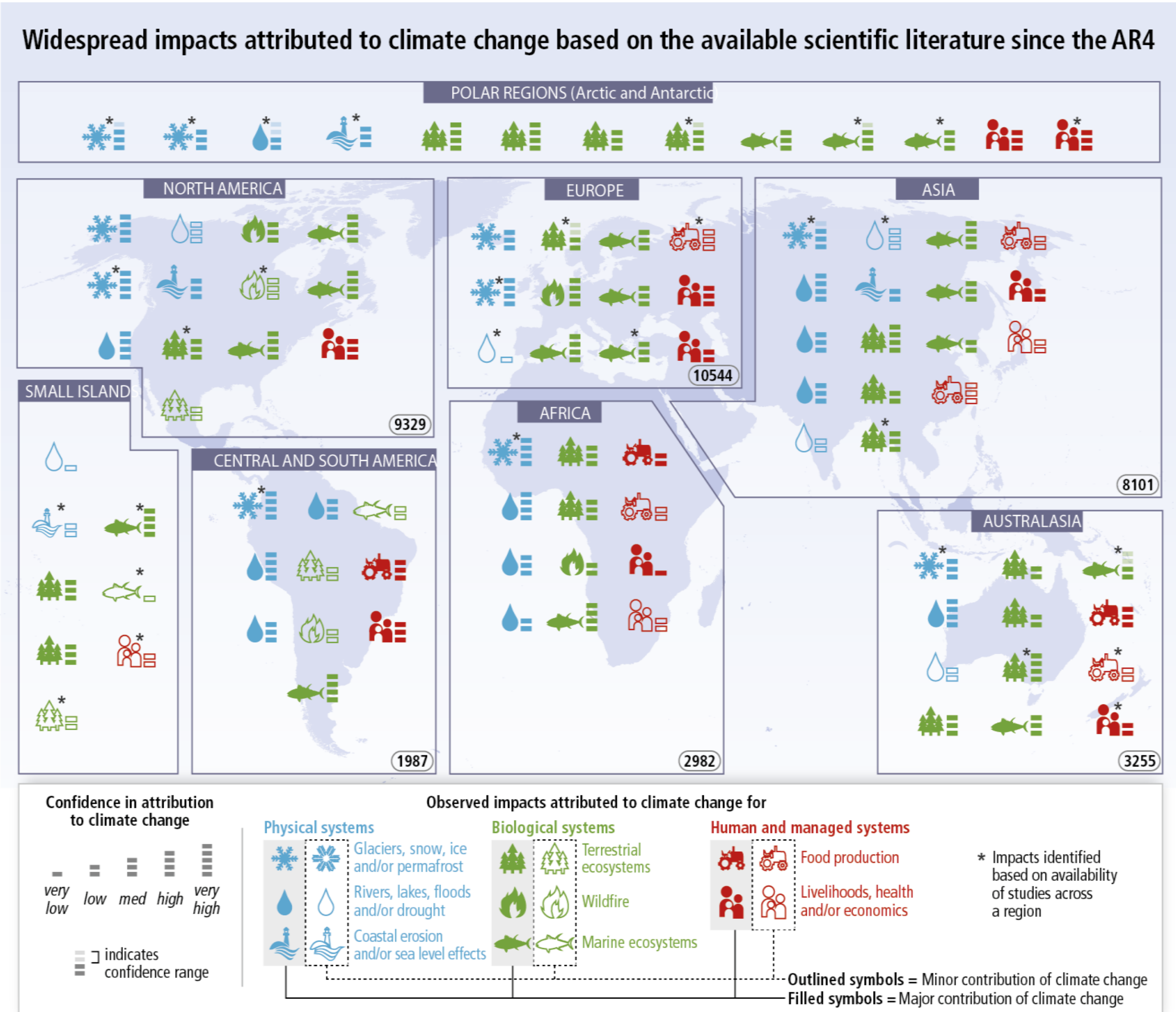


Figure 3.3. Global impacts planet with indicated link to climate change

*Symbols indicate categories of attributed impacts, the relative contribution of climate change (major or minor) to the observed impact and confidence in attribution. Numbers in ovals indicate regional totals of climate change publications from 2001 to 2010. Source: [1].*

Figure 3.3 shows a compilation of the IPCC where impacts of climate change are indicated for different parts of the world. Impacts are classified by the effect they have on the three systems: alterations in **physical** systems (glacial melting, thawing permafrost, changes in river hydrology, sea level effects, ocean temperatures), effects on **biological** systems (changes in ecosystems and increased fire risks) and effects on **human and managed systems** (food production and livelihood). Note that this is an overview of *known* effects. Absence from the map of additional impacts attributed to climate change does not imply that such impacts have not occurred: publications are still limited for many regions, systems and processes highlighting gaps in data and studies.

## 3.5. Combating climate change

To combat climate change and adapt to its negative consequences, countries have agreed to restrict the global temperature rise this century well below 2 degrees Celsius, compared to the pre-industrial era and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. During the Paris climate conference in December 2015, 195 countries agreed to this target. In the Agreement all nations (195 countries) agreed to undertake an ambitious efforts to combat climate change and adapt to its effects, with an enhanced support to assist developing countries to do so. The Paris agreement is unique in its kind: it is the first-ever universal, legally binding global climate deal.

# 4. Definition of Sustainability of renewable resources in the game

Often the mistake is made that a renewable resource, such as the sun, is also a sustainable resource. This is not always the case given that the sun is only the energy source. In order to harness its energy we need to capture it and transform it into something we can use, like electricity or heat. The process by which we capture and transform energy from the sun into something useful will ultimately determine whether it is also sustainable. In this chapter we will look at multiple aspects of the renewable energy sources as we try to determine what sustainable individual renewable resources really are. However, sustainability remains a difficult subject with many people holding an opinion on what it is and what it means. Sustainability is a difficult concept and is composed of many different factors. In literature definitions of sustainability are abundant and divergent. The Brundtland report provides the most popular notion of sustainability, namely - development that meets the needs of the present without compromising the ability of future generations to meet their needs -. [3, 4] Within this concept, sustainability is introduced as a balance between the present and future needs regarding quality of life. After the Brundtland definition the concept has developed in two different directions; so called “weak sustainability” that incorporates continued economic growth focused on the needs of humanity; and the so called “strong sustainability” which focusses on preserving nature and establishing balance. [4] A particular direction within the concept of strong sustainability is the triple-bottom line, [5] which explains a hierarchal order within which environmental quality (Planet) precedes social prosperity (People) and then economic prosperity (Profit), [5]. Without a functioning life support system societies cannot thrive; without social structures and institutions, economies cannot flourish. [4] Essentially, the foundation of life is the ecological structure that surrounds us and the natural resources on the Earth; damaging it in any way form or shape will jeopardize the planets ability to sustain a thriving future society and economy. Within this context, it can be argued that sustainability requires a balance between different interests, some more important than others, summarized in the triple bottom line concept by Elkington 1999, [5] - People, Planet, Profit – and further defined in PESTEL analysis. *“The PESTEL framework primarily concerns six factors: political, economic, social, technical, environmental, and legal. As a structured way to organize environmental factors, PESTEL is used to analyze and map how the external environment influences an industry.”* [1]. Both frameworks indicate the presence of multiple main elements (or stakeholders) within sustainability.


Fig. 3.1a. Triple bottom line principle

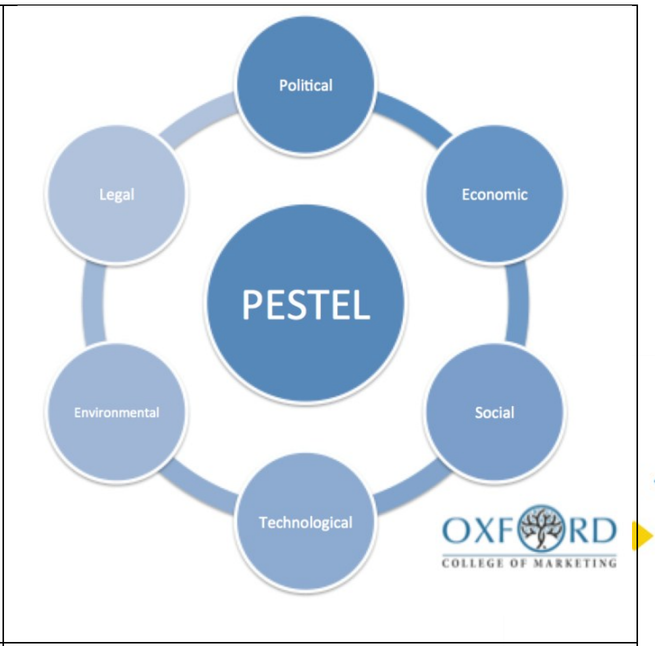



Fig. 3.1b. Elements of the PESTEL analysis

### 4.1. Seven elements of sustainability

Within the game the We-Energy Game defines sustainability into seven main elements and stakeholders and in order to achieve full sustainability all elements must be in balance. Every energy source card will have a score per element except for space which is represented by the game map and size of the playing cards.

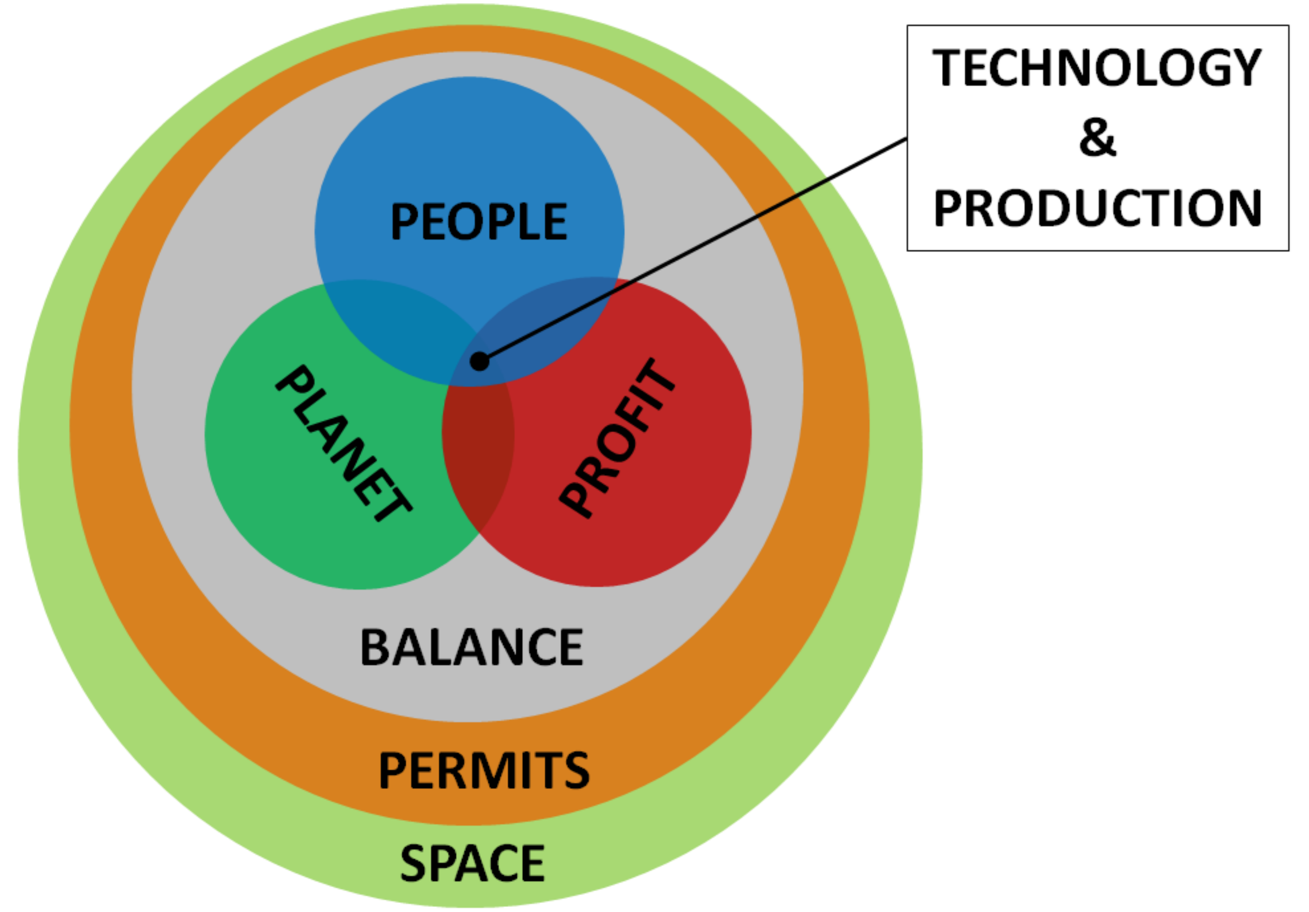



Fig. 3.2. Elements of sustainability used in this chapter

1. We start with the **PRODUCTION value** of the specific resource which indicates how much a specific renewable resource can produce in useful energy. This is often combined with the amount of space required for a specific renewable energy source. For instance a solar panel of 1 $m^2$ in the Netherlands produces roughly 120 kWh of energy per year. Many of the goals stated for renewable energy by the EU for instance are set out as a percentage of the total energy used or as an amount of **PRODUCTION**.
2. For renewable energy to be implemented **PERMITS** are often required and the authority to issue permits is in the hands of the government. This difficult process is often a political process with many stakeholders involved (often **PEOPLE**, **PROFIT**, and the government). The process and ease of getting a permit differs per country and often reflects the policies and laws of the government. For instance obtaining permits to build a big wind turbine in Germany is less difficult than in the Netherlands.
3. **PEOPLE** are the most difficult of elements as they represent the ones living near the renewable technologies or the ones that have a strong opinion on specific topics. **PEOPLE** have a strong opinion regarding renewable technologies. For instance, on safety or how they fit in the landscape etc. In the Netherlands this opinion can be very strong and may lead to resistance against specific technologies or plans.

4. The element **PLANET** describes the environmental damage which energy sources can inflict on the planet. We always think that renewables are also sustainable and this is partly true, but not always. The conversion of energy can still have an impact on the planet; for instance, during the production of solar PV panels greenhouse gas emissions or pollution is still produced. Therefore, the type of conversion process can negatively affect the **PLANET.**
5. The next element of sustainability is **PROFIT**. In order to attract investors, renewable technology must show themselves to be profitable. Therefore, renewable technology must be profitable although part of the income is currently based on subsidies which governments often extent for certain renewable technologies.
6. The element **BALANCE**, is often forgotten. The organizations responsible for balance (which in the Netherlands is e.g. Tennet, Enexis Liander) make sure that electricity or natural gas and /or other energy sources are always available for the consumer. Imagine a day without electricity! For some, especially those used to having electricity at their disposal 24/7, the idea alone is scary when you consider that you have no light, coffee, computers or internet and the list goes on… Now imagine that your energy is only produced by solar panels. Will you have electricity at night? **BALANCE** or the grid operators insure that we have energy available most of the time (in the Netherlands 99.99%). When adding intermittent renewable energy to the mix this task will become harder.

Additional element

7. When using renewable technologies **SPACE** is required to capture the available renewable resource like wind or solar radiation. This space requirement has an impact on your surroundings. For example, when placing solar panels on agricultural fields you cannot grow crops anymore. Also, some renewable technologies can harvest more energy than others for the same amount of space used.

# 5. RENEWABLE ENERGY SOURCES IN THE GAME

The main benefits associated with renewable energy, for instance Solar PV, Wind, and biogas production through anaerobic digestion, are the reduction of greenhouse gas emissions, reducing our environmental impact, and limiting the use of fossil resources. Renewable can be defined as: "energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat." [1] There are three primary sources of renewable energy sources namely the sun, the earth, and gravity (figure 30).

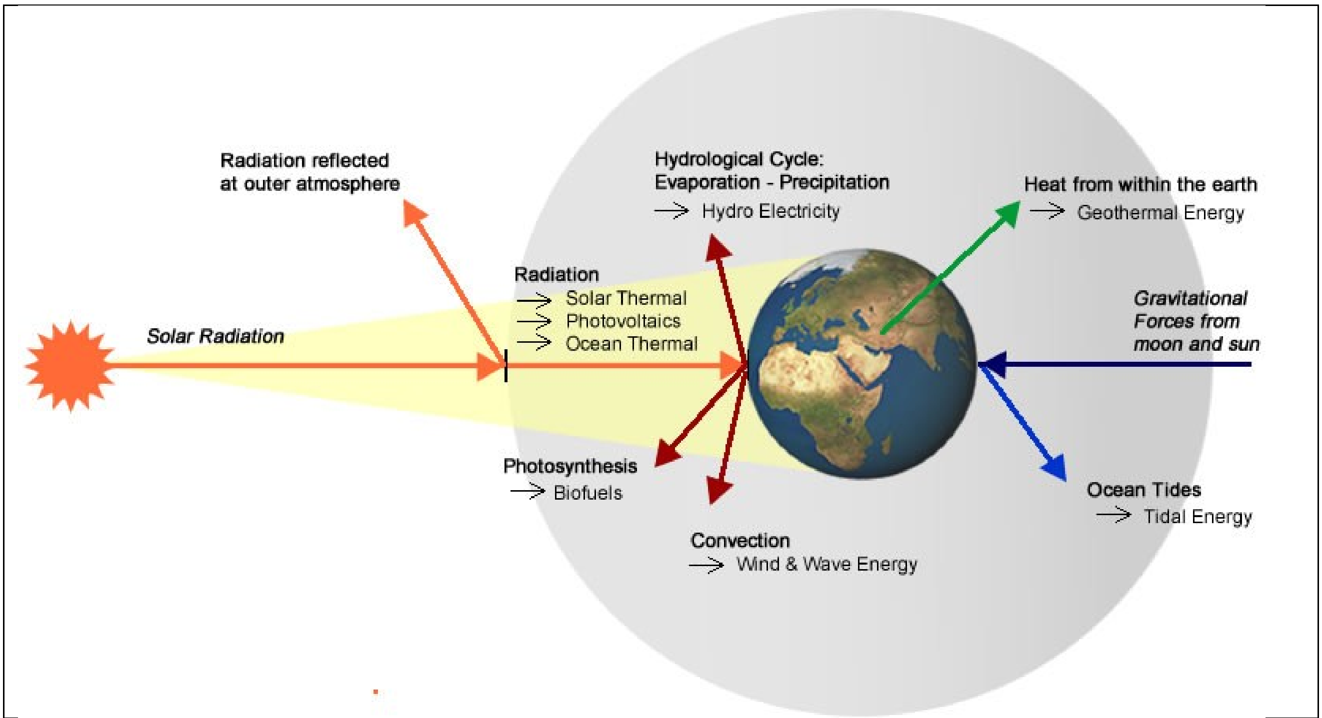



Fig. 4.1 Renewable energy sources on earth. [2]

1. The sun is the single biggest source of renewable energy on our planet. Its energy reaches the ground directly as light, but it also gets transformed into wind energy, ocean currents, rain, waves. Additionally, the light from the sun is transformed by plants into biomass and biomass over millennia of time is transformed in fossil fuels like oil, natural gas and coal. Accordingly even biomass and fossil fuels are a form of concentrated solar energy.
2. Geothermal energy is produced by the Earth and there are three main sources of heat in the deep earth: 1) Residual heat from when the planet formed. 2) Frictional heating, caused by denser core material sinking to the centre of the planet. 3) Heat from the decay of radioactive elements. It takes a long time for heat to move close to the surface (thousands of years). As a result, much of the planet's primordial heat, from its creations is still present in its core.
3. Gravity, the gravitational attraction of mass, has an effect on the Earth. The moon, the nearest large mass close to the Earth, and the largest objection in the solar system, the sun, both exert gravitational attraction on the earth and in particular on the earth's oceans resulting in tides.

## 5.1. SOLAR ENERGY

The sun is our single biggest renewable source of energy. At this moment the sun produces approximately 3.8 time 1026 Watts of energy, which is a three with twenty-six zero's, which is so big that there isn't even a name for this number. Whilst, most of that energy goes off into space, about 1.74 times 1017 Watts strikes the earth, which is still substantial enough. The sun delivers more energy in an hour than we as humanity consume in a whole year as can be seen in figure 34, which is an approximation of scale and not exact. Energy from the sun that reaches the earth still has a long way to travel before it touches the ground or your roof (figure 35) Overall, the average raw power of sunshine per square meter of south-facing roof in the Netherlands (on a sunny cloudless day) is roughly 110 W/m2, and the average raw power of sunshine per square meter of flat ground is roughly 100 W/m2.

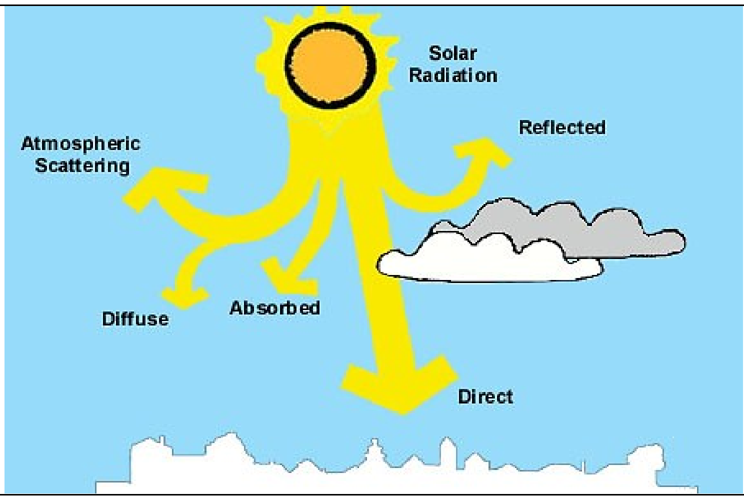



Fig. 4.3. : Loss of light from the sun before hitting the Earth's surface. [7]

Photovoltaic (PV) panels are able to convert sunlight directly into electricity. When sunlight hits the panels the energy in the light is transformed through the so called photovoltaic effect into electricity. -Typical solar panels have an efficiency of about 15%, where 15% of the energy in sunlight hitting the solar panel is converted into electricity; expensive ones perform at 20% and experimental ones even at 35 to 40%. - [10] For the highest production, depending on where you are on the planet, the panels need to be oriented towards the sun; in the Netherlands, for instance, the optimal angle is facing south at around 30 degrees (figure 41). Going more to the equator the angle becomes flatter towards 90 degrees.

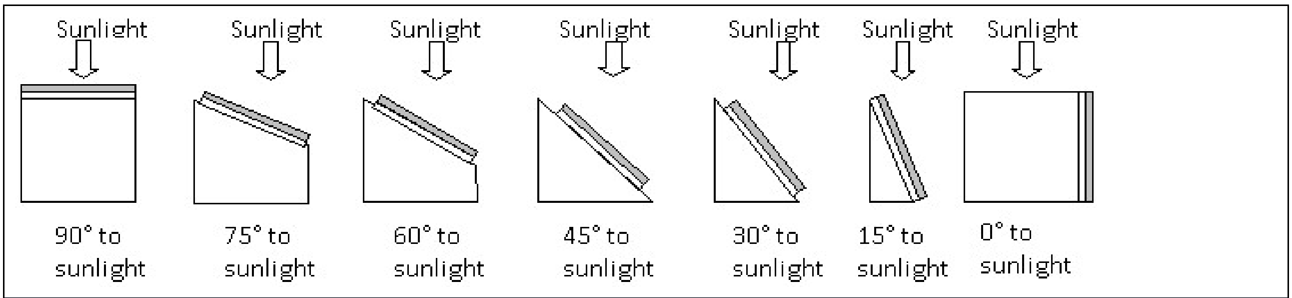



Figure 4.4: Solar panel at different angles towards the sun. [15]

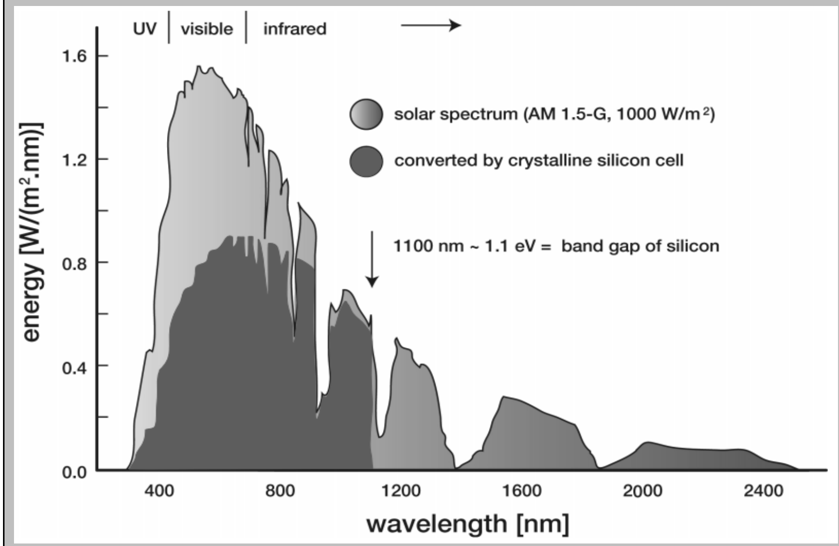
Solar panels can be easily placed on roofs of building or houses (figure 42a). Solar panels can also be installed en masse in so called solar fields. The solar field in (figure 42b) contains 26025 individual solar PV panels providing all the electricity needed for the households on the island of Ameland.

Fig 4.5a. Solar PV panels on a roof of a house. [16]

Fig. 4.5b: Solar PV panels in a large field. [17]

**LEARN MORE: Energy missed by solar PV panel**

The efficiency of solar panels is much lower than heat panels because they can only use a selection of the light that hits them. Light can be lost due to reflection or scattering. Also PV panels, depending on the materials used in their construction, are sensitive to a specific range of light also known as wavelength, see figure below. If light has too much energy only a part of this energy is used and if light does not have enough energy it does not get used at all. In the figure below the use of light of the widely used crystalline silicon PV panel (also seen in figure 42) is indicated together with to total amount of light hitting the earth.



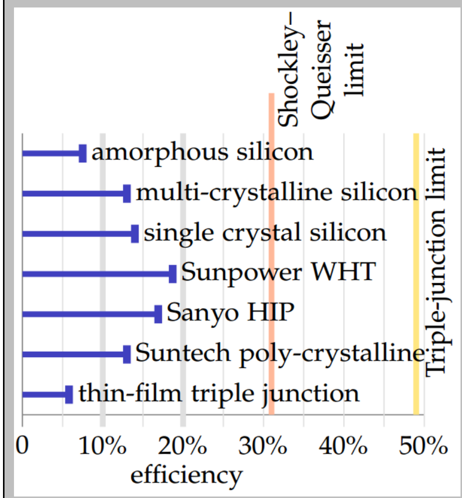




*Figure 43: Electricity demand vs. solar irradiation. [18]*

- Solar panels have a limit on how much energy they can extract from the sun called the Shockley Queisser limit. This limit refers to the maximum theoretical efficiency of a solar cell using a single p-n junction to collect power from the cell. Efficiency can be further increased by using multiple layers of different materials also called triple junction panels. - [19]

*Figure 44: - Efficiencies of solar photovoltaic modules available for sale today. In the text I assume that roof-top photovoltaics are 20% efficient, and that country-covering photovoltaics would be 10% efficient. In a location where the average power density of incoming sunlight is 100 W/m², 20%-efficient panels deliver 20 W/m². - [10]*

To give an indication of the overall sustainability of the technology we use the sustainability scores as indicated in chapter 3.1. The scores given per elements are relative and only give an indication of how the technology is seen today. Additional explanation will be given per element to clarify the chosen score.

### 5.1.1. SCORES SOLAR PARK AND ROOF

Within this section the scores used for the solar PV field ad Solar PV on rooftop renewable playing card are discussed per role in the game.

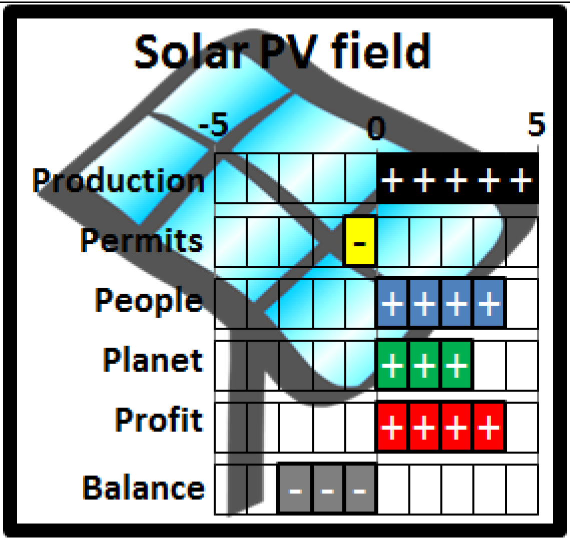



Fig. 4.6a. Scores of Solar PV field in the game

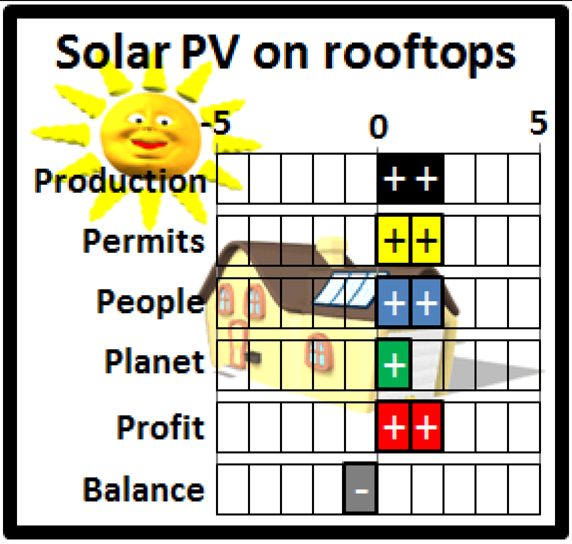



Fig. 4.6a. Scores of Solar PV on rooftops in the game

**PRODUCTION:** The average power delivered by south-facing 20%-efficient photovoltaic panels in The Netherlands and Britain would be for instance 20% × 110 W/m$^2$ = 22 W/m$^2$. Solar panels can easily be placed on rooftops if there are no obstructions etc. (figure 42a). A solar panel of 1 m$^2$ in the Netherlands produces roughly 120 kWh of energy per m$^2$ per year. Per unit of space solar panels produce more energy than wind and biomass making production very high; however, solar panels cannot be placed end to end as for the optimal production they need to face the sun and access paths are needed for maintenance. Overall, production from solar PV in fields receives a high score (Fig. 4.6a). PV on rooftops receives a lower score as not all rooftops are usable and there can be many obstructions (Fig. 4.6b).

**PEOPLE:** All over the planet solar panels are embraced by home owners, communities, and companies, due to the fact that they are easily integrated within the current energy system and they are easy to install on roofs or in fields; with the exception of monumental buildings and cities of course. Also, small solar PV fields are accepted in many villages in the Netherland and especially in Germany. However, some resistance to the creation of large solar fields can be expected as PV panels can scatter light around and pollute the current landscape view. The opinion regarding solar PV panels and fields can and will differ per village and even per person. The scores in the game are represented as positive for both Solar PF on the fields or rooftops as many local initiatives focus on PV first. Furthermore, relative to the production score, the points for solar PV on Rooftops score higher compared to the field (Fig. 4.6).

**PLANET:** Like with their heat producing brother, during use solar PV panels do not emit any harmful emissions. The biggest environmental impact is during construction where often fossil energy sources are used as part of the production process as well as toxic chemicals. The existing production process of these solar panels, therefore, is a big factor in their overall impact on the planet. - In past years the challenge has often been posed that "Manufacturing a solar panel consumes more energy than it will ever deliver." However, thankfully this is no longer the case. The energy yield ratio (the ratio of energy delivered by a system over its lifetime, to the energy required to make it) of a roof-mounted, grid-connected solar system in Central Northern Europe is 4, for a system with a lifetime of 20 years; and more than 7 in a sunnier spot such as Australia. Additionally, photovoltaic panels can become ever cheaper and less energy-intensive to manufacture, so their energy yield ratio will improve. - [10] Therefore, both solar PV on the field and on rooftops have positive impact on the environment (Fig. 4.6). PF on the rooftops scores relatively lower as it takes more effort to construct and placed compared to solar fields.

**PROFIT:** Solar panels have gone through a huge development in the past years and prices have been steadily dropping. It is now very profitable to place solar panels on your own roof in the Netherlands; however this is still very dependent on the regulations and subsidies given by the state. In some sunny countries electricity produced from solar PV is already cheaper than using fossil energy sources and that without any subsidization. Also placing solar panels in large parks can be very profitable in some countries including the Netherlands; where government subsidization makes both large solar parks and small private solar panels on your own house profitable. Therefore, profit is positive for both fields and rooftops (Fig. 4.6).

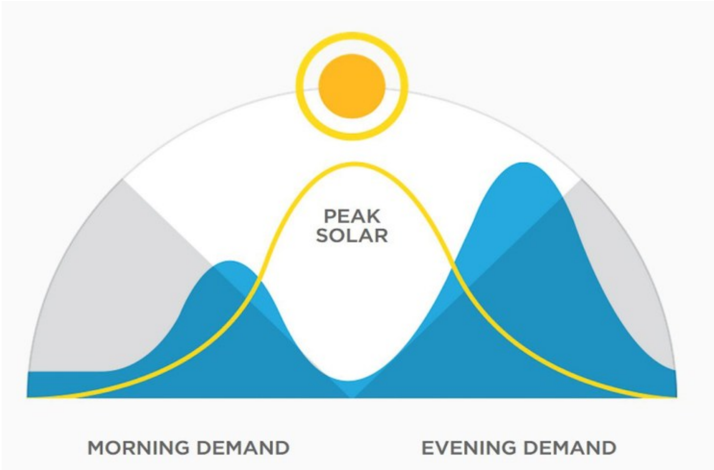



Fig. 4.6. Energy production of a solar PV panel compared to average consumption of energy for a household. [20]

**BALANCE:** Solar panels pose a problem for any grid operator especially without any form of control or storage. Solar panels produce a lot of energy during a limited amount of time during the day (fig. 4.6). At night there is no sun which equals no production. Also, passing clouds or other obstacles can hamper the production from solar PV panels. Therefore, PV panels can produce very erratically which does not help the grid operator at all. Also remember that solar PV panels can also be placed together in a field creating an even higher peak during midday. Looking to a whole year solar panels produce most energy during summer, whereas most demand electricity within the Netherlands is during winter. Therefore, solar panels score negatively for balance (Fig. 4.6). PV field score relatively worse as solar PV on rooftops are more dispersed over the electricity grid, lowering the imbalance problem per network area.

**PERMITS:** Getting a permit for solar PV panels on the roof of your house in the Netherlands is relatively easy. If your house is not a listed monument no permit is required at all, although you should not forget to inform your neighbors about your plans. Therefore, solar PV on rooftops score positive for permits (Fig. 4.6b). Getting a permit for a solar field is a different story, where in the Netherlands for instance a sophisticated process of politics is required to get the permits, where often many stakeholders and parties are involved (local government, provincial government, companies, residents, environmental organizations etc..). Therefore, solar PV fields score negative for permits (Fig. 4.6a).

**SPACE:** In the Netherlands placing solar PV panels in a large field often requires the sacrifice of agricultural land for the production of energy. For now this does not keep the milk from your table but if sufficient tracts of land are used for this purpose it will influence food production. Luckily there is also a lot of space available which is not used for agriculture, like roofs of houses or big factories for instance, or dykes (earth walls that stop water from flooding the Netherlands). For now, there is still a lot of potential room for solar PV.

## 5.2. WIND ENERGY

Wind energy is a very effective renewable energy source in Europe. Wind is created by differences in pressure, which are in turn created by cool areas and warm areas. The warm areas are created by the sun warming the earth. Therefore, wind is second-hand solar energy; see figure 50.

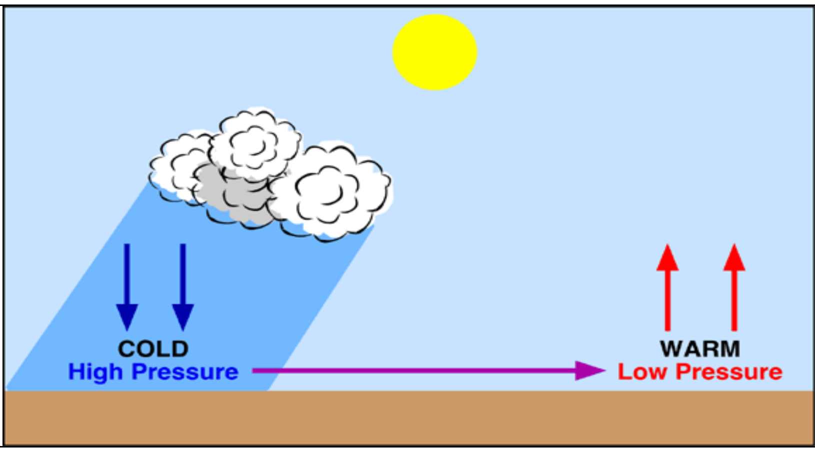



Fig. 4.7. Creation of wind on earth. [23]

Wind energy can be harvested using a wind turbine. Often well-known examples of these are the famous Dutch wind mills which were used for milling grain or pumping water as early as the 14th century. Currently wind turbines have evolved into monsters that can peak at almost two hundred meters high with a hub height of 120 meters and blades reaching almost 100 meters. In the world of wind turbines the bigger the better, as bigger wind turbines can produce exponentially more energy the larger the blade diameter. The blades of a wind turbine are shaped like wings on an airplane as they have a similar function. Passing wind must be transformed into a rotational motion of the blades which in turn is transformed in a generator into electricity (figure 51a). The technology to perform the aforementioned has come a long way since the first wood and cloth wind mills (figure 51b).

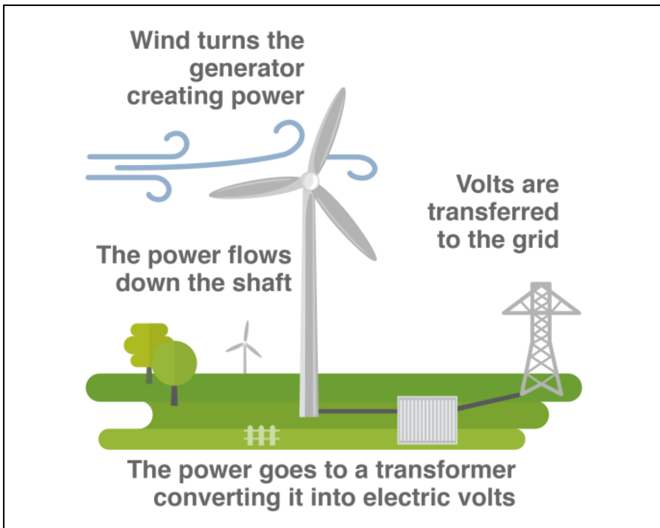



Fig. 4.8a. Basic workings of a wind turbine system. [24]

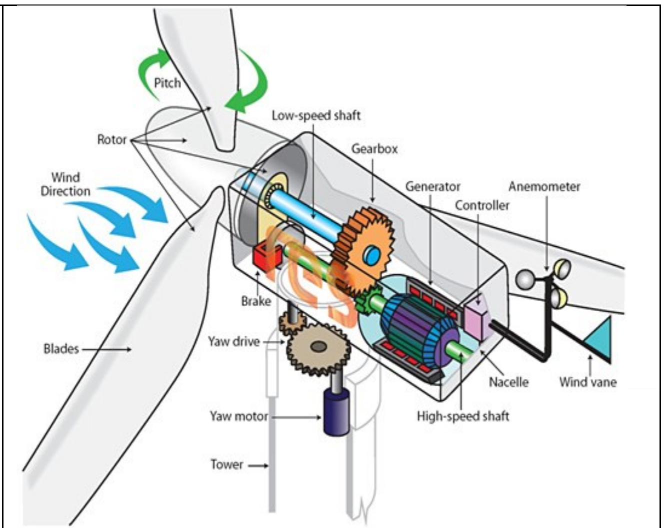



Fig. 4.8b. Basic workings of a wind turbine generator. [25]

At sea, winds are stronger and steadier than on land, so offshore wind farms deliver more energy per unit of space than onshore wind farms. However, offshore wind is more difficult to pull off because of the logistics of building and maintaining at sea and the corrosive effects of sea water. At a big Danish wind farm, Horns Reef, all 80 turbines had to be dismantled and repaired after only 18 months' due to exposure to the sea air. Other wind parks (Kentish Flats UK) seem to be having similar problems with their gearboxes, one third needing replacement during the first 18 months. Also the higher you are from the ground the steadier the wind as it is not interrupted by any objects like houses, trees, etc...

| | |
|---|---|
|  |  |
| Fig. 4.9a. Offshore and onshore wind Germany. [26] | Figure 4.9b. Offshore and onshore wind Germany. [26] |

**LEARN MORE: Theory of wind turbine**

The fuel of wind turbines is of course the wind and the amount of energy which can be extracted from the wind depends on a number of factors. The density of the air (ρ) determines the mass of the wind going through the turbine. The area of the blades (A) determines the surface area of wind. The wind speed determines the amount of air passing over the blades. With these elements the energy in the wind entering the blades can be determined. By calculating the energy in the wind after the turbine blades using the surface after the wind turbine and the remaining air speed the absorbed energy by the wind turbines can be determined. After the energy is transferred in a rotational form of energy there are some remaining losses in for instance the gearbox and the electric generator.

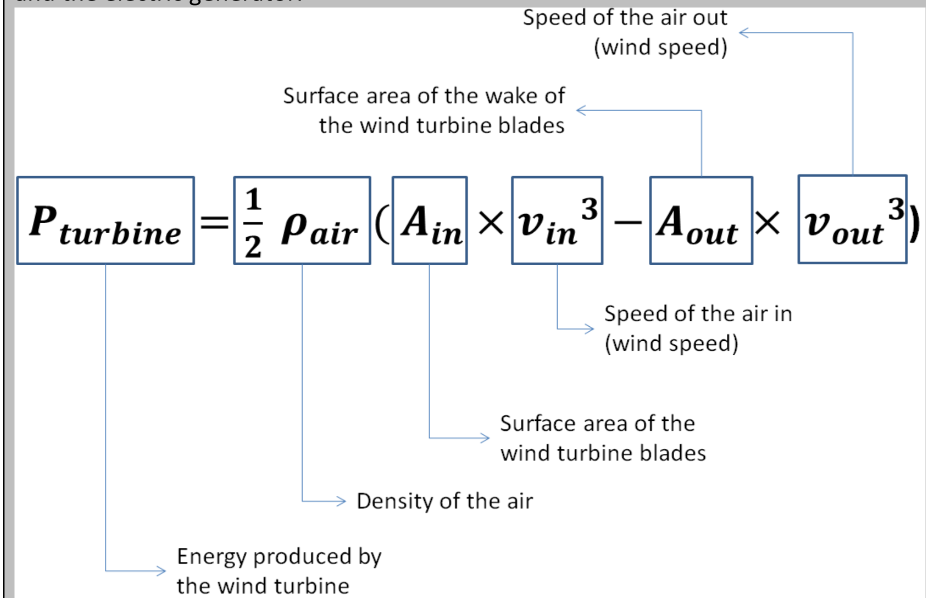



*Figure 53: Offshore and onshore wind Germany. [26]*

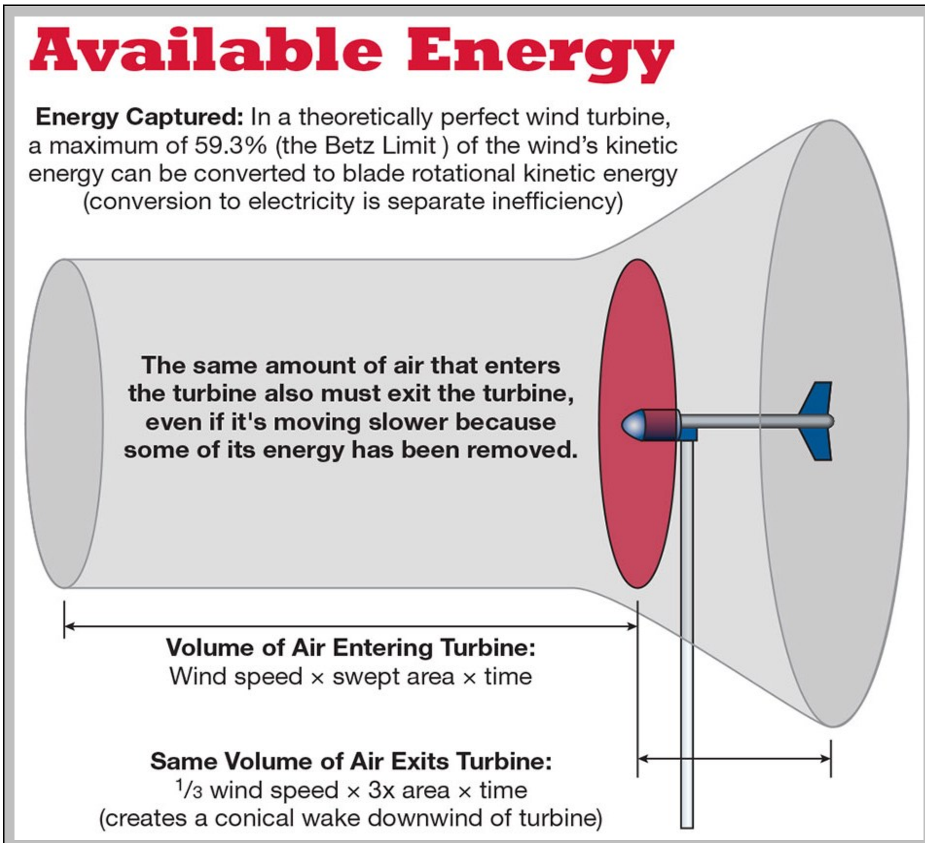



*Figure 54: The maximum theoretical energy input of wind turbine (Betz limit). [27]*

The capacity of wind turbines have progressed substantially in the last years as new materials and technologies are developed.

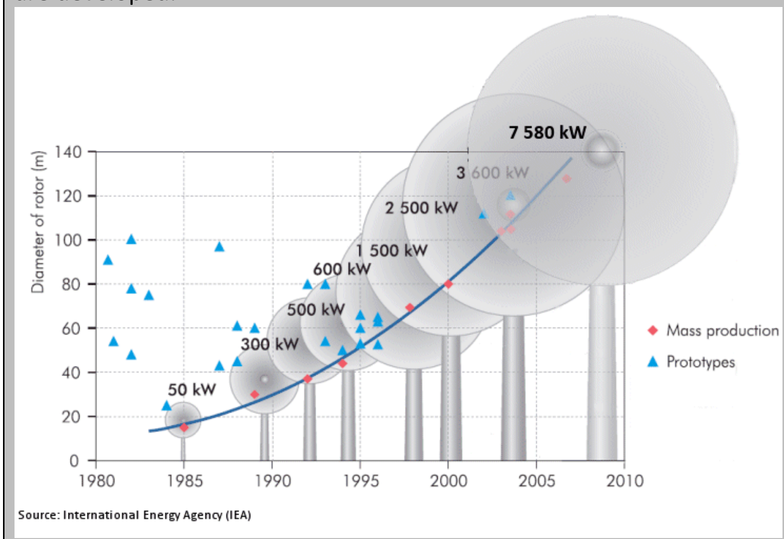



*Figure 55: Size and rated power wind turbines. [28]*

**Further reading**
https://en.wikipedia.org/wiki/Wind_power

### *5.2.1. SCORES SMALL AND BIG WIND TURBINES*

Within this section the scores used for the small and large wind turbine playing cards are discussed per role in the game.

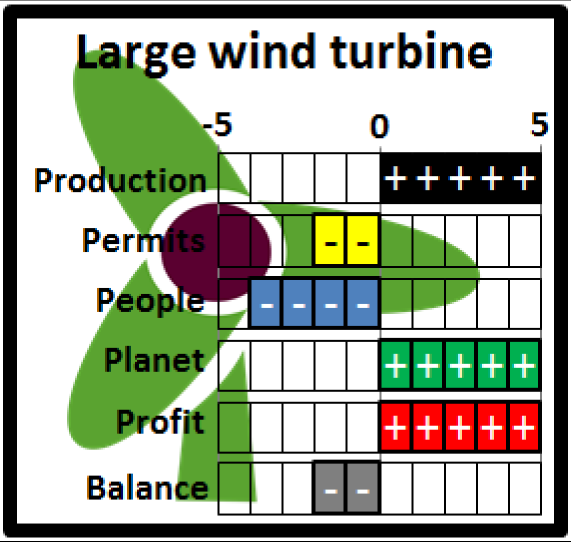


Fig. 4.7a. Scores of large wind turbine

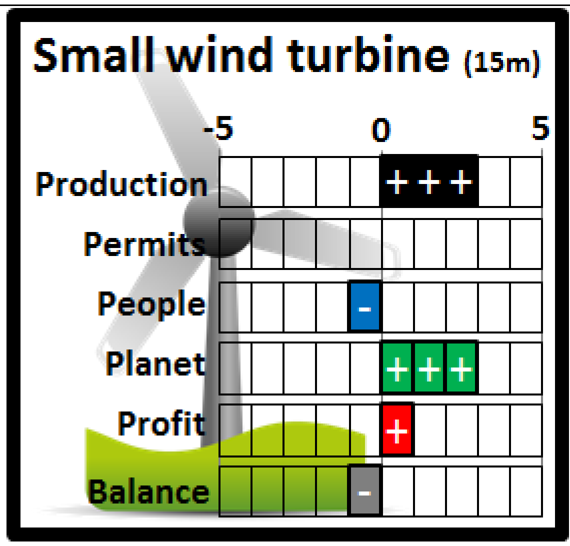


Fig. 4.7a. Scores of small wind turbine

**PRODUCTION:** Wind turbines placed in windy areas like The Dutch coast (Onshore) of North Sea (Offshore) can be very productive. We could perform the analysis in production per hectare of land in which solar panels are more productive on average in the Netherlands, however, the land use of wind or solar PV are completely different. Still, to give an indication one turbine (of 2 MW) produces around half the energy per $m^2$ of solar PV around 60 kWh of energy per $m^2$ per year. However, this is where the comparison ends as wind and solar are two completely different technologies. Additionally, solar PF does not always cover the entire surface available as discussed in section 4.3.1. Therefore, the scores of large wind and solar PV field are assumed similar in the game (fig. 4.7a). The production of smaller wind turbines of approximately ten kilowatts is lower per unit of space as they get lower wind speeds at lower high, have more obstructions, and are less efficient. Therefore, small wind turbines score lower than their big brothers (fig. 4.7b).

**PEOPLE:** Within the Netherlands people are very sensitive for their surroundings; therefore, onshore wind projects meet a lot of resistance. The main arguments used are horizon pollution, noise, and the impact on birdlife. Therefore, when planning wind turbines onshore it is important to include the local population. When the benefits of the wind turbines (and not only the drawbacks) flow back to the local inhabitants attitudes towards wind turbines may change. There are villages in the Netherlands which own their own wind turbine and with it all the benefits. For these villages, the wind turbine has become an icon in their village and evokes positive emotions. On average scores for wind turbines are negative for both the large and small turbine. For the big wind turbine the score is more extreme as it has a bigger impact on the surroundings (Fig. 4.7a) where a small turbine will still have an impact but substantially lower (fig. 4.7b).

**PLANET:** Wind turbines with a lifetime of 20 years can have an energy yield ratio of 80, which means they produce 80 times more energy than they consume. The energy consumption of a wind turbine includes its construction, placement, maintenance, and finally removal. The fuel for the wind turbine is of course for free (at least for now); therefore, this energy yield ratio is usually high. This will also result in a low environmental impact, with most of the impact during the construction and deconstruction phase and required maintenance. However they still have some disadvantages. The spinning blades of the wind turbine for instance kill birds. It's been estimated that 30,000 birds per year are killed by wind turbines in Denmark, where windmills generate 9% of the electricity. This should be placed in perspective, given that traffic kills one million birds per year in Denmark, which is thirty times greater (Thirty times greater incentive to ban cars!). And in Britain, 55 million birds per year are killed by cats (fig. 4.8). - [10] Of importance here is to look to the species of bird being killed and their abundance in nature. Overall, wind turbines score very high relative to their production on planet (fig. 4.7).

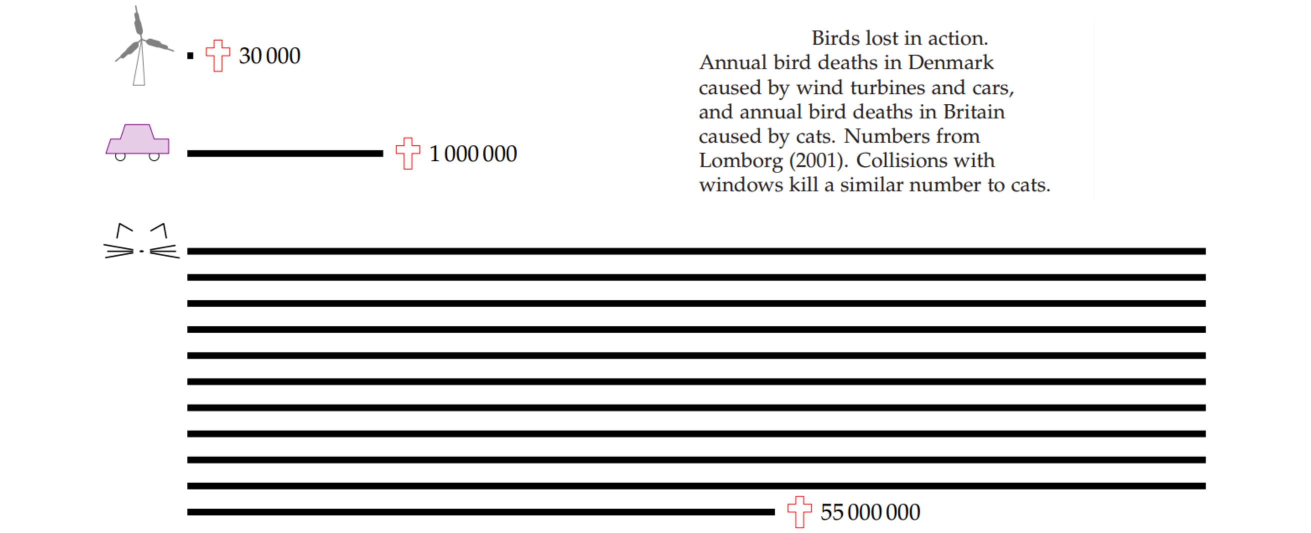



Fig. 4.8. Causes of death in bird population. [10]

**PROFIT:** Currently within the Netherlands wind turbines are very lucrative as they can be very profitable. This is true for both offshore and onshore. However a large share of this profit is still based on subsidization from the government. This subsidization of wind (Called, wind SDE+ 2018) accounts for around half of the total income over the lifetime of a wind turbine. However, wind turbine development is at a high pace and is getting close to the point where it can be profitable without any government subsidization, especially when constructed in large parks. Big wind turbines are the most profitable (fig. 4.7a), where small turbines only have a small profit due to their lower production and relatively higher cost (fig. 4.7b).

**BALANCE:** Unfortunately, the wind is unpredictable and inconsistent over the course of a year. This means that there could be moments when there is no production coming from wind parks. Of course, we could ask people to not use electricity whenever the wind stops blowing; however, so far this has not been accepted. Therefore, back up production must be available at all times to fill in when the wind production takes a dip. Doing this will cost additional money. Also, currently this stand by production is often in the shape of fossil power plants. Wind turbines cannot be placed close to each other as they would compete for the wind. However, looking at actual ground use is only minor (around 2% including road etc.) meaning that the land is still available for agriculture or industry (off course an airport would be difficult). Overall, wind turbines produce more regular than solar panels and big turbines more regular than small turbines relative to production. But still unpredictable and, therefore, wind turbines score negative on balance (fig. 4.7).

**PERMITS:** Getting a permit for wind turbines is a difficult process, especially on land. In the Netherlands, there is a lot of resistance against large turbines which makes the process complicated. Currently on average in the Netherlands for a large wind turbine on land it takes 5 to 12 years to get a permit, if you are lucky enough that is. For wind offshore this process is somewhat smoother as governments often dedicate large areas for offshore wind where potential owners can participate. Also there is often a lot less resistance from the local communities (sea creatures do not have a vote). Fishermen sometimes complain as offshore wind farms are off limits for them and the fish know this (at least this is what fishermen suspect). Getting a permit for big turbines on average is more difficult than for small turbines (fig. 4.7a). In the province of Groningen small wind turbines less than 15 meters require fewer permits (fig. 4.7b).

**SPACE:** Wind turbines require a large amount of space and preferably somewhere where there is plenty of wind. Turbines cannot be packed closely together as there will not be any wind left for the last turbine. A benefit of wind turbines is that the ground under a wind turbine remains usable as agricultural land, as opposed to using solar PV panels. Additionally, wind turbines occupy a considerable amount of airspace due to their height so placing high wind turbines near an airfield will not be an option. Further reading: https://www.nrel.gov/docs/fy09osti/45834.pdf

## 5.3. BIOMASS

Biomass can be defined as all growing plants on land or in the oceans or green stuff. All available bioenergy solutions involve first growing green stuff, and then doing something with the green stuff. Within this line of thinking we can directly use the green stuff to make energy or we use waste products. - [10] Direct use of biomass could include; burning wood in a power station that produces electricity or heat or both; turning Rape seed into ethanol or biodiesel, and use that to power our cars, trains, planes or for use in other places where such chemicals are useful; or turning Maize into biogas for replacing natural gas or also for transport and chemical industry. - [10]

| | | |
|---|---|---|
|  |  |  |
| Fig. 4.11a: Biomass wood [21] | Fig. 4.11b. Biomass maize [21] | Fig. 4.11.: Biomass Rape seed [21] |

We can take by-products from agricultural activities, from road sides, our own kitchen, or toilet and use them for the same processes named above, but then only using waste products. Of course there is always a limit to the amount of waste products available and the quality is much lower. - [10]

| | | |
|---|---|---|
|  |  |  |
| Fig. 4.12a. Biomass roadside grass [21] | Fig. 412b. Biomass harvest remains [21] | Fig. 412b. Biomass domestic waste [21] |

### *5.3.1. BIOGAS PRODUCTION FROM BIOMASS*

Biogas is produced when organic material is left to decompose in an air tight container. This reaction where bacteria break down organic material in the absence of oxygen is called Anaerobic Digestion. The process produces a gas which consists mainly of methane 50-60% and Carbon Dioxide 40-50%. The methane in biogas is very important as it is a flammable gas (Gas used from the gas grid is also mainly methane), which can be converted into energy. To produce biogas a complicated system is needed that produces biomass for use in the plant, transports the biomass to the plant, stores and pre-treats the biomass, heats and stirres the biomass in the digester, processes the biogas into useful energy, and handles the left overs of the process called digesatate. With biogas you can do three main things:

1) Combust it in a Combined Heat and Power unit (or CHP unit), to produce electricity and heat.
2) Burn the biogas in a boiler to produce only heat.
3) Or upgrade biogas into green gas, similar to gas from the gas grid, and inject it in the national gas grid for later use, to do either step 1 or 2.

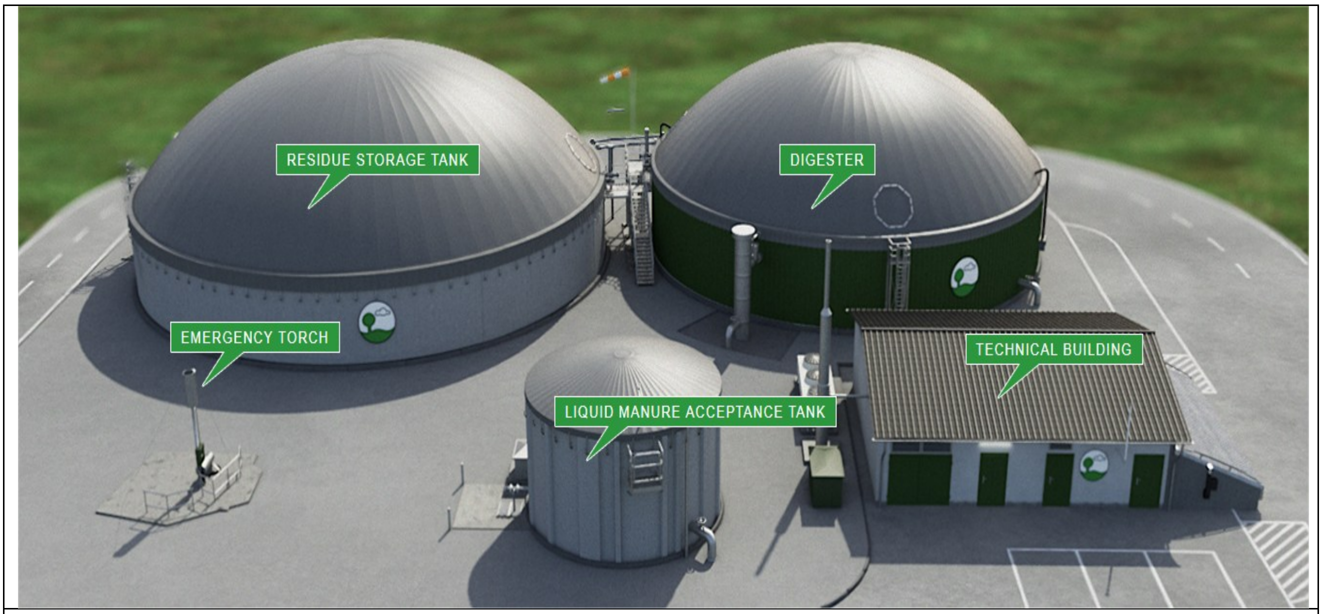


Figure 48: Main layout of farm scale biogas installation in Europe. [22]

**Additional info**
Video on biogas systems: https://www.youtube.com/watch?v=5RswjCWaR6I
Interactive animation: http://www.envitec-biogas.com/microsite_envitec/#en

To give an indication of the overall sustainability of the technology we use the sustainability scores as indicated in chapter 3.1. The scores given per elements (people, planet…) are relative and only give an indication of how the technology is seen today. Additional explanation will be given per element to clarify the chosen score.

## *5.3.2. SCORES OF BIOGAS PRODUCTION FROM BIOMASS*

Within this section the scores used for the biomass playing cards are discussed per role in the game.

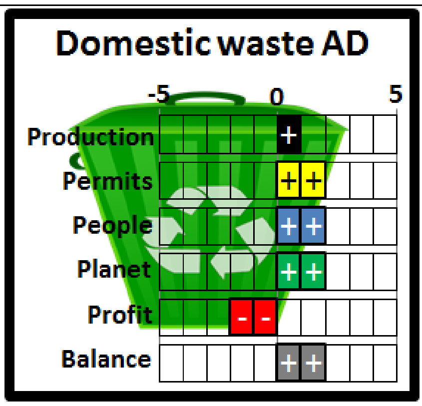


Fig. 4.9a. Scores of domestic waste biomass source

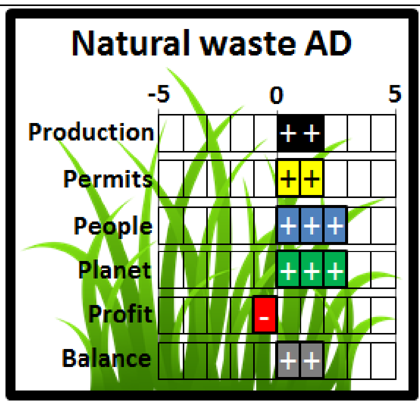


Fig. 4.9b. Scores of harvest remains waste biomass source

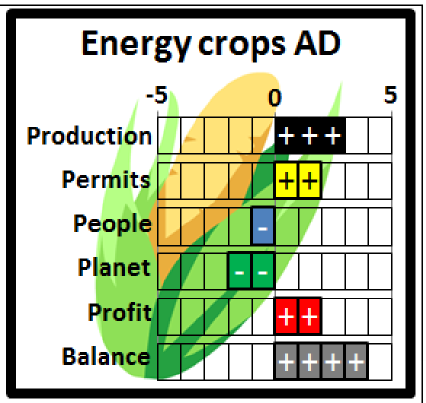


Fig. 4.9c. Scores of domestic waste biomass source

**PRODUCTION:** The most efficient plants growing in Europe are about 2%-efficient at turning solar energy into carbohydrates, which would suggest that plants might deliver 2 W/$m^2$ (If we assume 100W/$m^2$ for the Netherlands); however, the efficiency of plants drops at higher light levels, and the best performance of any energy crops in Europe is closer to 0.5 W/$m^2$ (figure 49). This is only the fuel for producing useful energy. When producing heat from it we might be able to capture 90% of the energy in the biomass, but when we make electricity or biogas we can only capture 50% of the energy in the biomass. We can conclude from this that the production of energy from biomass per unit of land is terribly low. However, biomass has other advantages and there is often waste biomass available in one form or another.

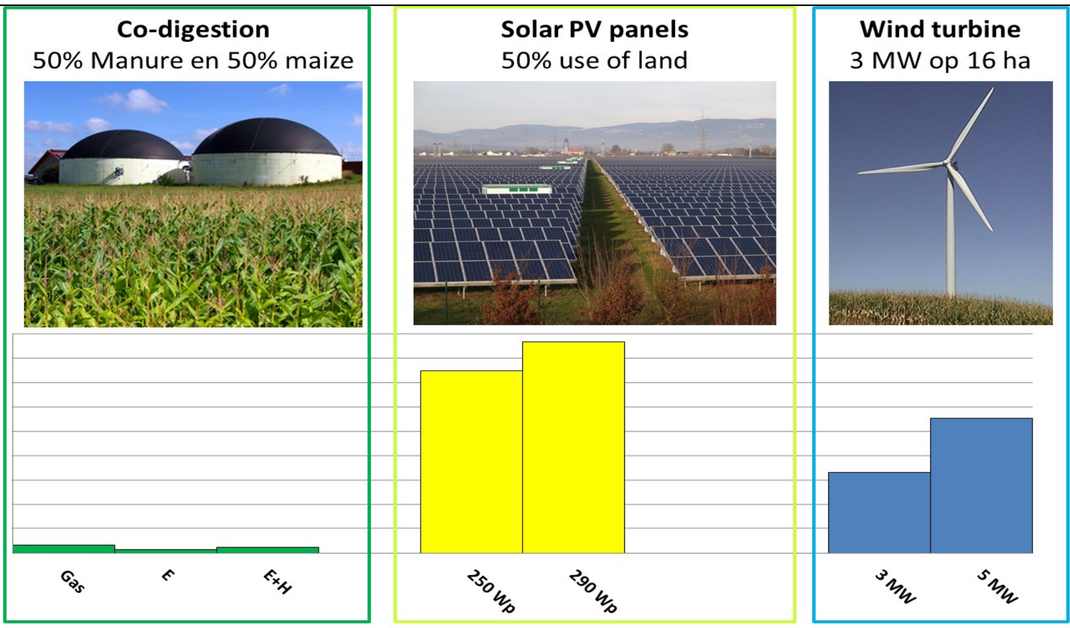



Fig. 4.13. Effective energy production of three renewable energy source.

Overall biogas production from biomass is low and depends on the quality of the biomass. This is represented in the game where maize produces more than a harvest remains which in turn produces more than domestic waste (fig 4.9).

**PERMITS:** Getting a permit for a biogas installation is not an easy task in the Netherlands. First of all you need a building permit, followed by an environmental permit or report. Additionally, biogas needs subsidization from the government called SDE to be profitable. Often getting these permits takes years of dealing with several parties and government institutions ranging from local, provincial, and national governments and getting SDE is like playing in a lottery. Overall, biogas has less difficulty compared to wind or solar as the installation is smaller and can be placed on a farm or industrial area. Additionally, owned agricultural land can be utilized for growing energy crops or harvesting harvest remains. Within this context a positive score is given for permits, given the right location (fig 4.9).

**PEOPLE:** The position regarding biogas is mixed in the Netherlands, for instance in the northern part (in the province called Friesland) There is a lot of resistance against mostly larger biogas installations located close to villages. Their main argument is the smell and of course the sense of safety. Also, large biogas installations have high consumption rates and therefore require a large and consistent supply of biomass, which will result in an increase of traffic in often quiet countryside villages. Within the game focus is placed on the biomass, with the assumption that the biogas installation is not close to populated area. Within this context, maize scores negative as it sacrifices agricultural land and is a high crop. Domestic waste and harvest remains score positive as using waste is seen as environmentally friendly and is therefore accepted (fig 4.9).

**PLANET:** Biomass is a complicated story when considering the environmental impact as there are many processes in which biomass can be turned into useful energy. However, these processes tend to be more complex than a solar panel (which turns sunlight directly into electricity). For instance, if we look to electricity production from biomass using Anaerobic Digestion; we first need to grow or collect biomass, then transport it to the processing plant, then we need to process this biomass to produce biogas, and finally we need to transform this biogas into electricity. All the processes aforementioned will require machinery and consume energy each stage of which adds to the potential environmental impact. Much of the machinery used in the process of making biogas also still run on fossil fuels such as trucks and tractors. For energy crops specifically grown for energy production a negative impact is assumed as the process is based on intensive farming.  For biomass waste products a positive score for planet is assumed as there is no intensive farming process included (fig 4.9).

**PROFIT:** Creating a positive business case differs per use of biomass and per country. For instance, in the Netherlands biomass used in coal fired power plants is currently profitable, whereas Anaerobic Digestion or biogas production on small farms is generally not. The latter is also due to the complexity of the system as the fuel, biomass, is not for free, it must be collected and transported to the processing plant. All these operations add to the costs of the use of biomass. Within the game the scores for energy maize are positive for profit; when growing own energy crops more production from the higher quality biomass will result in more production and therefore higher revenues (fig 4.9). However, the low quality of waste biomass combined with the added cost of collecting the waste results in a negative impact on profit for domestic and harvest remains (fig 4.9).

**BALANCE:** Biomass can be seen as stored sunlight and when stored correctly can retain its energy for a long time (before decaying for instance), which effectively makes it storage of energy. This stored biomass can then be burned or digested when needed, making it flexible. Also when processed for instance in biodiesel it can also be stored for a longer period of time. Biomass can be used and is available when wind and solar PV are not. Also, the production of energy out of biomass (or the process) can be controlled, we are in control of the gas pedal, whereas for solar and wind Mother Nature is in control of the gas pedal. However, in reality this flexibility is limited as the complex processes are difficult to start up or down quickly and the availability of the fuel (biomass) is also limited. For the game the scores for balancing are positive, especially for energy maize as the production is much higher (fig 4.9).

**SPACE:** The use of space for biomass production is substantial as the efficiency of plants is very low (they capture only a small amount of the sunlight in biomass (figure 49). This means that if we want biomass to provide a lot of energy we will need to use a lot of agricultural land. Furthermore, producing biomass for energy replaces other uses of the land for instance producing food for animals and people. When using waste products like agricultural waste or food leftovers the required quantity of land can be reduced; but of course, there is only a limited amount of waste available.

## 5.4. STORAGE

Storage of energy can be done in many ways shapes and forms. On average all storage systems have the same main properties. Storage means that surplus electricity is changed into another kind of energy to be transformed and used again as electricity in a period of production shortage, which means loss of energy. Each energy transformation needs energy. So, it is always more efficient to match supply and demand without storage.

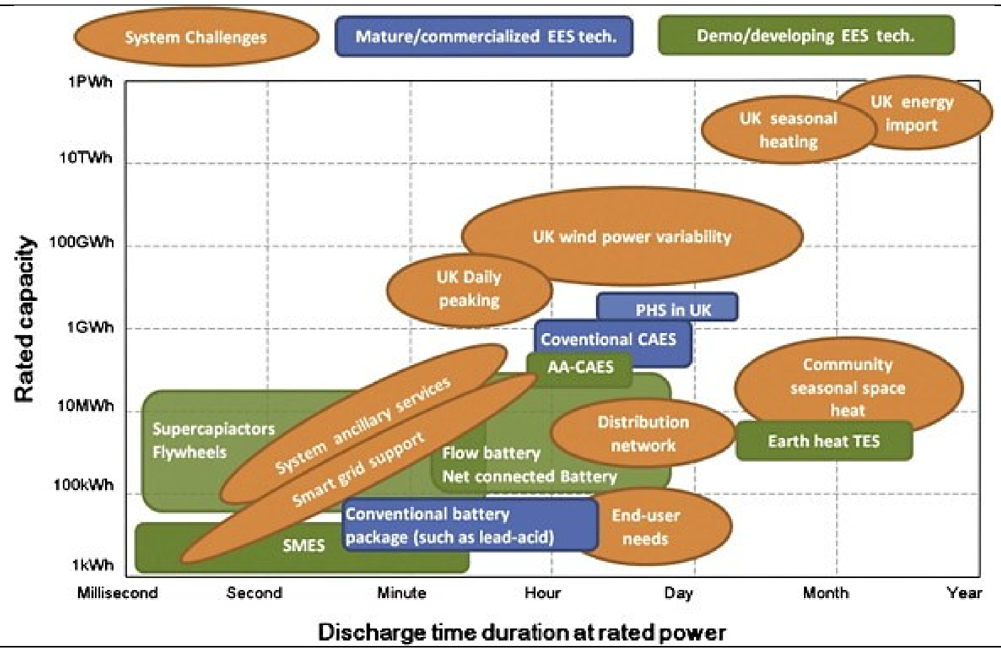


Fig. 4.14. Different type of storage technologies. [36]

For example, let's take the rechargeable batteries of your phone. This battery when full has a specific amount of energy contained within, also called capacity. When you use your phone the things you do with your phone will determine how long the battery will last; if you call a lot and use Wi-Fi the phone will be empty sooner as compared to only using the clock on your phone. This is called discharge rate. When the battery is empty it will require time to recharge your phone; how long this will take is determined by the charge rate. Both during charging and discharging energy is lost in the process. For the battery in your phone on average 10% is lost. There is also something called self-discharge, if you leave a charged battery for long enough it will lose energy over time and ultimately be empty.

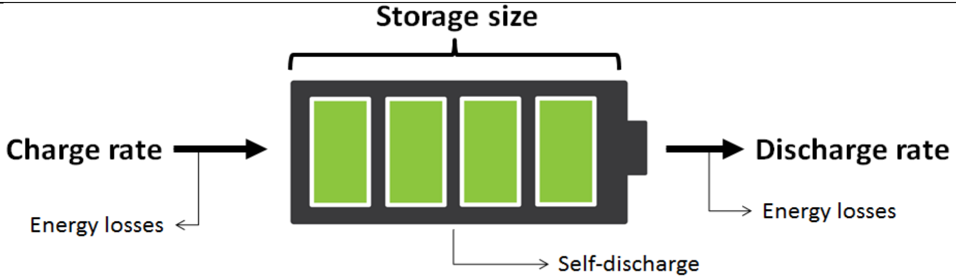


Fig. 4.15. Overall definition of an energy storage system

### 5.4.1. SCORES OF BIOGAS PRODUCTION FROM BIOMASS

Within this section the scores used for the biomass playing cards are discussed per role in the game.

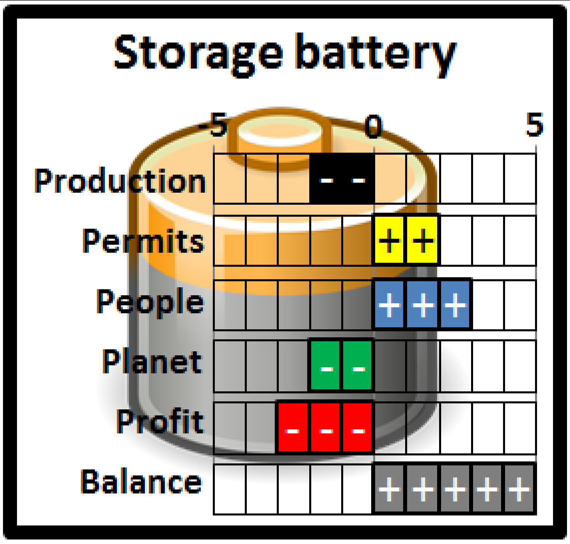



Fig. 4.9a. Scores of energy storage in the shape of a battery

**PRODUCTION:** The production of a battery from an energy source is actually negative as the battery absorbs energy before it can release it again. During the process of charging and discharging energy is lost which ranges per technology used; for example, an lithium battery used in most phones and laptops loses around 10 to 20 percent of the energy put in the battery. Therefore, production of the battery playing card is negative for production (fig 4.9).

**PEOPLE:** The people score for batteries is difficult to determine as they have not been around for a long time. Within the game the score for people are positive as products like the Tesla power wall and the electric car public opinion is generally positive within the Netherlands (fig 4.9).

**PLANET:** Most batteries in use today are based on electrochemical storage where energy is stored in a chemical reaction, for instance in lead or lithium batteries. The production of these batteries and their individual components including mining transport and finally disposal has a substantial impact on the environment. Therefore, the scores for the battery are negative for planet (fig 4.9).

**PROFIT:** Currently batteries are very expensive with prices for an tesla power pack of around 7000 to 8000 euros including installation within the Netherlands. Additionally, batteries do not receive subsidization where solar, wind, and biomass do, this mainly because batteries do not produce energy. Batteries can produce cash flows by storing or buying energy on the national energy market when it is cheap and selling it when it is more expensive, however, this included still makes the business case very thin (fig 4.9). Therefore, in the game profit has a negative score.

**Table 5**. The main properties of lithium battery storage

| | Capacity kWh | Power out kW | Power charge kW | Efficiency % | Self-discharge %cap/hr | Price ($C_{hh}$) €/kWh[a] | Source |
|---|---|---|---|---|---|---|---|
| Main properties storage system | 13.20 | 7.00 | 5.00 | 89% | 0.008 | € 530.00 | [2, 3] |

[a] Per unit of storage capacity installed following a linear price range

**BALANCE:** One thing batteries excel at is storing access energy and making at available when it is in demand. (fig 4.9).

**PERMITS:** Getting (fig 4.9).

**SPACE:** The power wall is small enough to fit in a households

# 6. ORGANIZING A WORKSHOP

The we energy game can be played to create awareness regarding local energy transition, however, this must be performed in combination with a clear goal for the workshop and professional workshop leaders.

## 6.1. Determining goal and scope of the workshop

Before starting an We-Energy Game session it is important to define the goal and intended results of the session and the scope of the session.

**Setting the Goal:** It is important to know beforehand what the goal of the workshop is to select the needed elements that contribute to the goal. Goal could include for a We-Energy Game session:

1) Awareness: The game can help in creating awareness in the complexity of energy transition; indicating what is needed in terms of renewable resources, what the strengths and weaknesses are of specific renewable resources and which roles or stakeholders play an important role in a local energy transition towards renewable sources. Additionally, to create awareness the We-Energy Game can also be combined with master classes on transition related topics.
2) Acceptance: The game can help facilitate discussions between stakeholders and or the general public to explain the necessity of the energy transition, what this might mean for them, and to discuss what is acceptable and not regarding the integration of renewable resources. Within the discussion also the responsibility of the stakeholders can be discussed.

**Determining the scope:** The scope of the planned session will determine what will be discussed during the workshop and what type of map will be printed or used for the We-Energy Game. The We-Energy Game can use pre-selected maps consisting of a small village as introduction to the game and a city as the main challenge of the game or a specific area can be indicated and printed for specific workshops. The map (Fig. 5.1) is based on open street map information and any location can be selected for use in the We-Energy Game. The only condition is the scale and with it size of the map, which must be fix to accommodate the space actor in the game of a fixed size per renewable playing card.

## 6.2. Preparations before the workshop

The W-Energy Game is printed on A0 format (Fig. 5.1). When playing the We-Energy Game the selected area or the game map can be of importance in shaping the discussion (Fig. 5.1 indicated in red), therefore, the map section of the game can be adapted to fit any open street map selection of a curtain size and scale. The size of the map is around 60 by 60 centimeters.

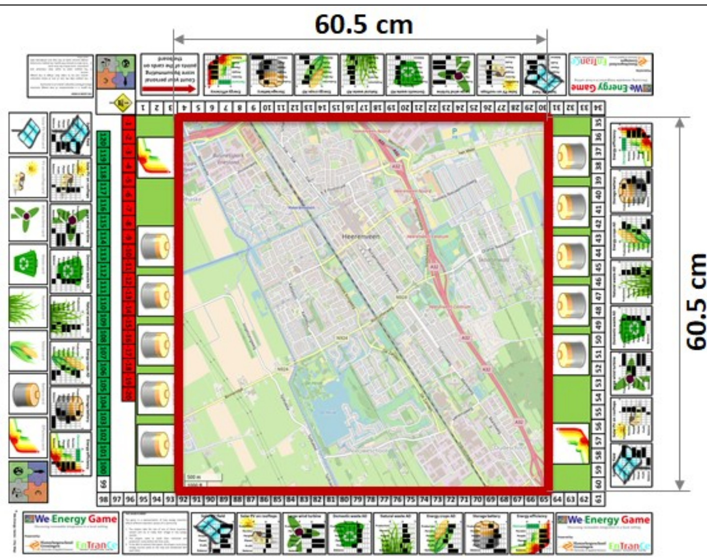



Fig. 5.1. The map section on the We-Energy Game

The game map can be selected using OpenStreetMap where an area can be selected. Zoom in till reaching a scale of 500 m (Fig. 5.3a) and then select a square including the scale (Fig. 5.3b) using print screen. Paste the selected area in the game and expand to 60 cm bij 60 cm. Afterwards, check if the scale is comparable in size with the renewable playing cards (It does not have to be perfectly exact in the game).

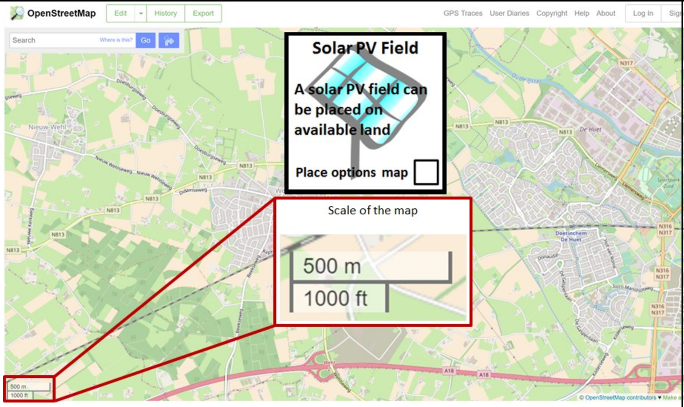



Fig. 5.3a. OpenStreetMap website indication of scale https://www.openstreetmap.org

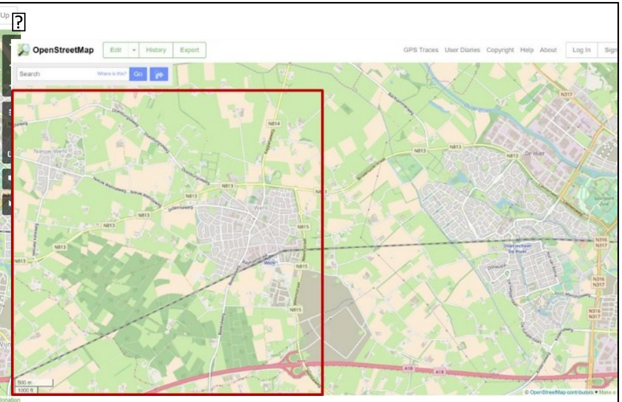



Fig. 5.3b. OpenStreetMap website https://www.openstreetmap.org

## 6.3. Set up of the tables

The table should be big enough to hold a full A0 map or 120 cm by 90 cm (Fig.5.4). Most often the ideal situation for playing the game is when seated (The game can also be played using standing tables) requiring at least six seats on the table.

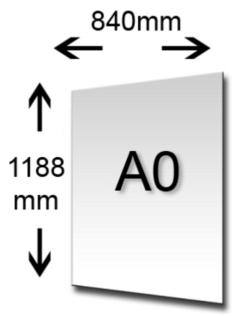



Fig. 5.4a. A0 format

Fig. 5.4b. The layout of a single table with the game

On the table first the city map is played and over this the village map. When the maps are placed on the table the playing card, role cards and pawns can be placed. After this the game is ready for use.

## 6.4. Introduction presentation

The introduction of the game including a brief introduction of the gameplay is given in the presentation. With this information the players can get started, however, additional instructions from the game instructors is needed in the beginning of the game.

## 6.5. Guiding the game

As facilitator and instructor of the game the start of the game is important. During the first round or introduction round the players are asked to select a role (we often advise to pick a role that the player is not in real life) and then to already pick their favorite card (or card that gives the most benefit for his or hers role). After this every role is allowed to place their cards one after the other starting with the chairmen and then; Permits, People, Planet, Profit, and Balance. The facilitator helps in this round, showing how to place cards and how to count the scores using the pion. After all players have played their favorite cards often there is a division between the scores of the roles where Production, Planet, Profit are positive and People, Permits, and Balance are negative or close to zero.

## 6.6. Discussion after the game

The game is an excellent tool for shaping the discussion

## 6.7. Finalizing the workshop

## 7. HOW TO PLAY THE GAME

The We-Energy Game is a role playing game where 5 or more players embark on a discussion how to make a village or city energy neutral for electricity using renewable technologies and energy efficiency.

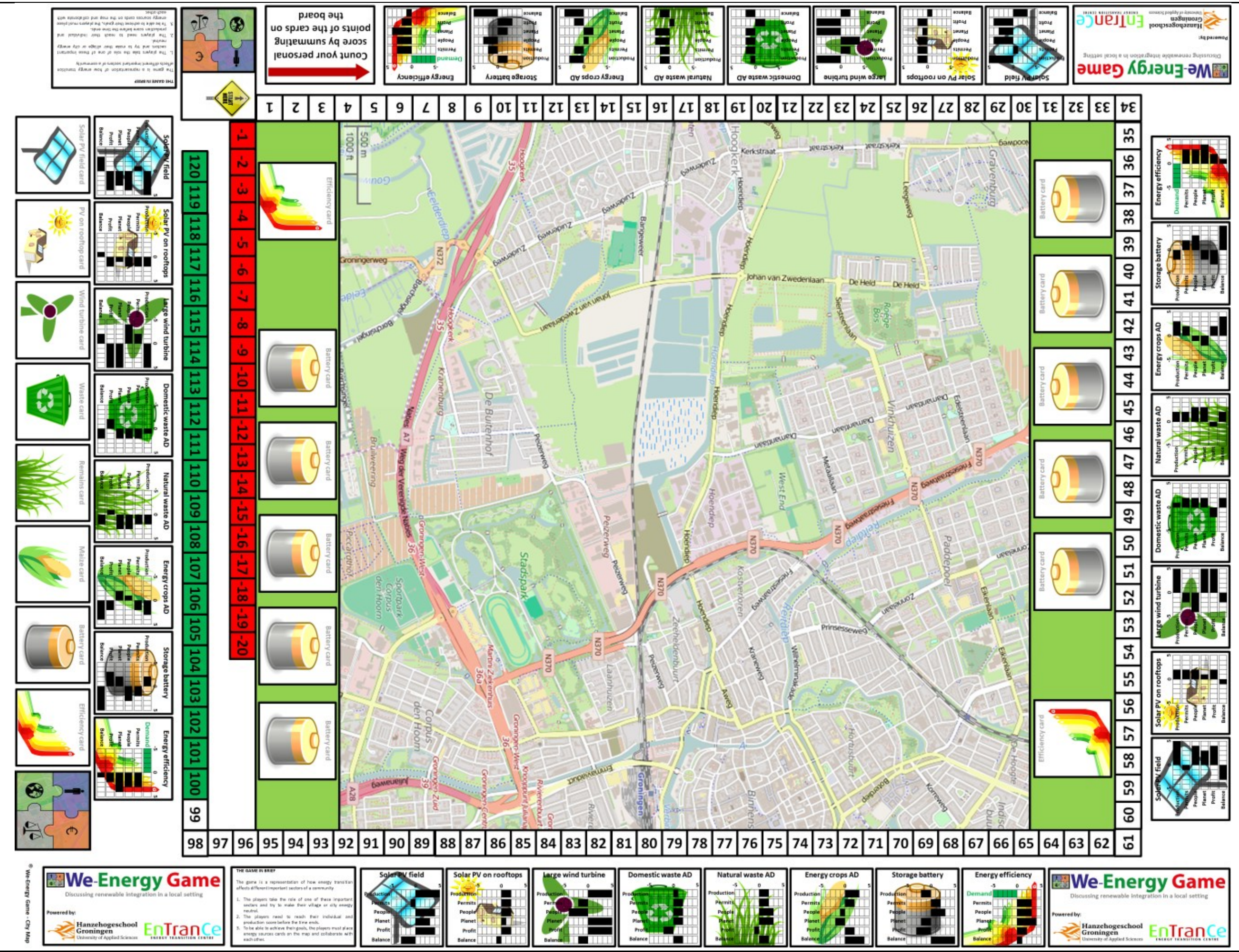
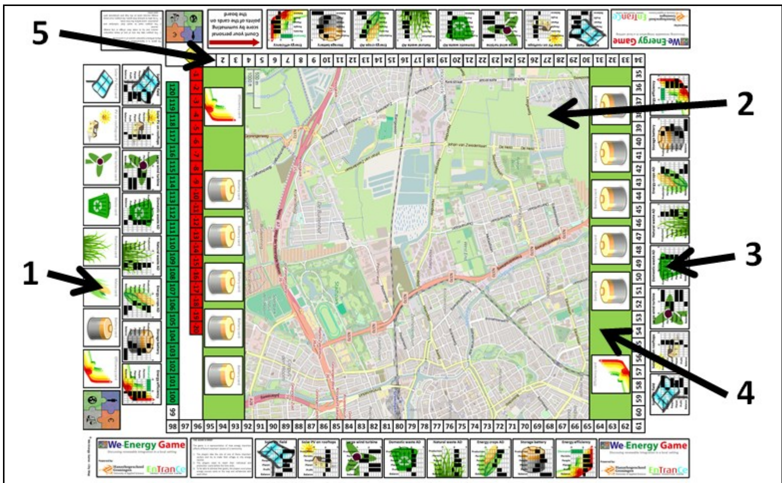
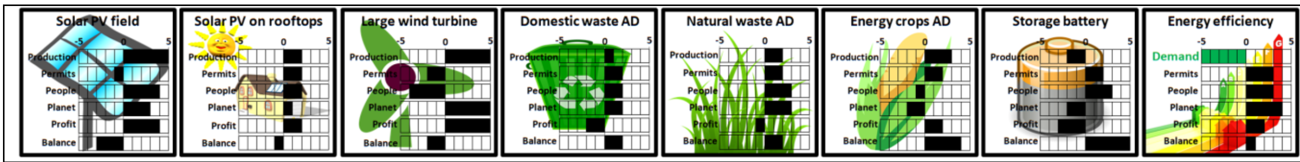



Fig. 5.1. The We Energy Game




**Numbers in the figure**

1) Place for the Renewable Source cards
2) The Game map
3) The scores of the source cards
4) Place for none space related source cards and additional game cards
5) Score line for courting score individual roles


Solar PV field
Solar PV on rooftops
Large wind turbine
Domestic waste AD
Natural waste AD
Energy crops AD
Storage battery
Energy efficiency
Production
Demand
Permits
People
Planet
Profit
Balance
-5
0
5