**Introduction**:

- These cards describe the cost, size and impact of different options for building a low-carbon energy system in northern Europe, sufficient to supply 1 terawatt hour (1 TWh) of energy per year.
- 1 TWh is enough to power all the energy needs of 50,000 people - electricity, heating and transportation.
- The challenge with the cards is to select the options which provide a secure, well-balanced energy system at reasonable price, with limited carbon dioxide ($CO_2$) emissions and a low environmental footprint.
- The pack has 52 playing cards comprising the four main categories of an energy system - energy Resource (R, 13 orange cards), energy Storage (S, 13 blue cards), Power supply (P, 13 green cards) and Network component (N, 13 grey cards). A viable energy system needs one compatible card from each category, as defined at the bottom of the picture on each card.
- Some cards are repeated to allow you to build an energy system larger than 1 TWh, for a bigger population and/or to trade power.
- Each technology has a letter (R, S, P or N) and a number to help link the four categories in a viable energy system. To get an initial idea of what a viable energy system looks like, you can start by choosing your own favourite technology in the energy Resource category (R) and then build on that by finding one compatible card from Storage (S), Power (P) and Network (N).
- Each technology has six properties. Coloured boxes are used to show whether the values are favourable (green), neutral (yellow) or unfavourable (red) based on mid-case values of ranges from a variety of sources up to April 2024.
- In addition, there are three bonus cards to mitiigate $CO_2$ emissions using carbon capture and storage (CCS) or natural sequestration through the uptake of $CO_2$ by plants.

**Game 1 - Trump Cards (two or more players, easy)**

- The objective is to win all the cards in play.
- The pack is divided equally among the players, each hand placed faced down. Any surplus cards are set aside.
- Each player looks at their top card, initially without revealing it to the others.
- The first player chooses the property on their top card which they think has a favourable value, typically those with a green box indicating low total cost, low surface area, low annual emissions, high operating life, high economic benefit or high controllable supply. The player announces the property and its value.
- The player with the best score wins all the cards in the round and puts them at the base of their pile. It is then the winner's turn to choose the property on the top card which is used in the next round. If two or more players have the same winning value, then the cards are left in the centre and these players play again with the same category until one person wins them all.
- If a player has no cards left, then they are out.
- The winner is the player who has all the cards whilst everyone else is out.

**Game 2 - Build Your Own System (one player or one team, moderate difficulty)**

- The objective is to build a viable energy system which fits your own preferences by freely selecting compatible cards in the pack which would supply at least 1 TWh per year.
- It is easiest to start with an Energy Resource (R) that you like and then use the information at the bottom of the card to find an appropriate Energy Storage (S) technology, then a Power Supply (P) and then a Network Component (N). You need one element from each category for a viable energy system.
- You may wish to generate more than 1 TWh per year to make money by selling power through a Subsea Interconnector. In which case, you can choose, for example, to produce 3 TWh by choosing three cards from each category, R, S, P and N.
- You can test different ideas and configurations by assessing the pros and cons of the different properties.
- You can calculate the expenditure required for your energy system by adding up the Total 20 year costs. For example, a 1 TWh/year energy system based on Onshore Wind (R1), Pumped Hydro Storage (S1), Pumped Hydro Power Plant (P1) and an Upgraded Grid (N2), costs €1550 million (600 + 300 + 150 + 500) over 20 years. The breakeven electricity price in Euros per MWh is the summed Total in € million divided by 20 for each 1 TWh per year. In the example, the breakeven price is 1550/20 = €77.50 per MWh.
- You can also add up the Annual $CO_2$ emissions and Surface Area to judge the environmental impact and footprint of your system.

**Game 3 - Working Twins (2-4 players, moderate)**

- The objective is to build two viable energy systems, each comprising four compatible cards, one from each of the four categories: R (Resource), S (Storage), P (Power) and N (Network).
- The three pink bonus cards are removed and the rest of the pack is divided into the four categories, R, S, P and N. These four piles are shuffled and two cards from each pile are dealt to each player.
- The rest of the cards are put in four separate draw piles according to their category, face down.
- The top card from each pile is turned over and placed in front of the pile. Discarded cards will be placed here during the game.
- Each player looks at the eight cards in their hand without revealing them to the others. The compatible elements in the four different categories are defined in the lower part of the picture on each card – these are what players use to decide which cards they need to exchange in order to build a viable energy system.
- In turn, each player chooses one card from any category, either the upper discarded card or from the top of the draw pile and then discards a card of the same category from their hand, face up on the discarded cards. When all the cards in any of the draw piles have been used, the cards beneath the top of the discarded cards are shuffled and placed face down to form a new draw pile.
- The winner is the first player to build two viable energy systems.

**Game 4 - World Beater (2-7 players, challenging)**

- The objective is to make a viable energy system with either the lowest cost or lowest emissions from a four-card combination of Resource (R), Storage (S), Power (P) and Network (N).
- The three bonus cards are removed from the pack, which is then shuffled and four cards dealt to each player to form their hand.
- Another two cards are placed face-up in front of each player. The remaining cards are placed face-down to form the draw pile, the top card of which is turned over to form a discard pile.
- Each player looks at the four cards in their hand without revealing them to the others.
- In turn, each player either:

  a) takes the top card from either the draw pile or from the discard pile and discards a card from their own hand onto the discard pile; or

  b) exchanges a card from their hand with one of the face-up cards in front of them; or

  c) moves one of their face-up cards to the bottom of the draw pile, replacing it with the top card from the draw pile; or

  d) exchanges one of their face-up cards with a face-up card belonging to another player.

  With action d), the newly acquired card is turned face-down for one round meaning that it is out of play until the player's next turn when it is turned face-up again.

- At the end of their turn, any player may call out that they have a "World Beater" in their hand, based either on the Total 20 year cost or on the Annual $CO_2$ emissions, provided that:

  i) they possess the four parts of a viable energy system; and

  ii) in the chosen properties of the four categories there are at least two green boxes and no red boxes.

- The other players then have one more round to try to complete their own energy systems, after which everyone reveals their hands.
- Those players who possess viable combinations then add up the four relevant values from each part of their energy system. The winner is the player who has a viable energy system with the lowest total cost or lowest total emissions, depending on the call.