Educator's Guide

ENERGETIC is a four to six player collaborative game. You work as a team to build a carbon-neutral power grid, while managing the region's public opinion, grid stability, and money.

cards:

action deck

random event decks

role cards

https://newyork.thecityatlas.org/energetic/

In this Guide, you will learn more about each of the game's mechanics that describe the politics, infrastructure projects, community and regional cooperation, and decision-making that must define the next decade, as well as the climate impacts that we will have to overcome together.

Can you keep the lights on in 2035?

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A Bit About Energetic

What is Energetic?

We designed a board game about the future of New York City. Energetic gives everyone the chance to see the scope of change and cooperation needed to transform the city's energy demand and supply in time to meet goals for the Paris Agreement.

In the game you play from 2021 to 2035, a turn each year. You must balance your budget, your grid stability, and your public opinion to keep the lights on, win elections, and build 16 gigawatts of clean power for the city. Then you will have replaced all fossil fuels, provided there is a matching reduction in demand from behavior change and efficiency.

Who is Energetic for?

Everyone! Energetic's high degree of realism makes it an entertaining, effective learning tool, and it can be played by anyone from teenagers to postdocs. During development, Energetic was enjoyed by people ages 11 to 60, including middle school students, energy Ph.D.s, former commodity traders, and leaders at environmental NGOs. Games are in use by players at organizations including Carnegie Mellon, Vanderbilt, Cornell Tech, Con Edison, Hunter College High School, and the New York State Department of Energy.

Studying energy is a back door way to learn about how our lives will change, and why. Young people will see new careers, older people may want to switch careers, and all players come away with a detailed view of the benchmarks we need to hit, and by when.

Why should I play this game?

Many of us are concerned about the climate crisis but don't yet have a clear picture of what concrete options are available to meaningfully address it. Our objective is to give players a quick grounding in what solving climate change actually means, in a physical and social sense, based on the demand for energy and the types of renewable or carbon-neutral generation that can supply 8 million New Yorkers.

As you play, one thing you'll realize is that this problem is big, and our response must be too. This means, among other things, that it will be visible. A single Solar piece (see pages 18-19, Solar) represents building a piece of infrastructure nearly half the size of Manhattan. A single Wind piece (see pages 20-21, Wind) represents the construction of 170 metal structures, each nearly as tall as the Eiffel Tower, miles off the Long Island coast. The energy transition modeled in Energetic needs to happen with emergency speed if we are to maximize our chances of avoiding a Hothouse Earth. **And yet, if you are not noticing it around you, then it is not happening.**

It is clear that if we are to meet the urgency of this crisis, we must all push in the same direction. We hope playing this game can make your role in the coming decade more effective, better informed, and more powerful, and that by providing a tangible vision of what part of the solution looks like, society can begin the necessary step of reorienting itself towards this larger goal.

It's a lot of fun, too!

Energy and Power

What is energy? What is power?

Energy is a quantity, while power is a rate. Specifically, power is the rate at which something uses energy.

Energy = Power x Time

When a 10 watt bulb is turned on, it continuously uses 10 W of power. If it is left on for one hour, then it has used 10 watt-hours (Wh) of energy. 10 Wh of energy would also be used by a 5 W bulb left on for two hours.

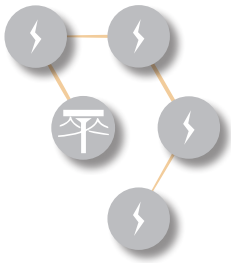
Most rates are measured in some other unit per unit time, like miles per hour, or population change per year. Because power is measured in watts, and so we don't say per unit time, it's easy to forget that it is a rate. But the unit watt is just another name for a joule per second.

Watt = Joule / sec

It can be helpful to think of power and energy as analogous to water and water flow, say when drawing a bath. In this case, power would be the speed at which water comes out of a faucet, and energy would be the amount of water accumulated in the bathtub.

What is a power grid?

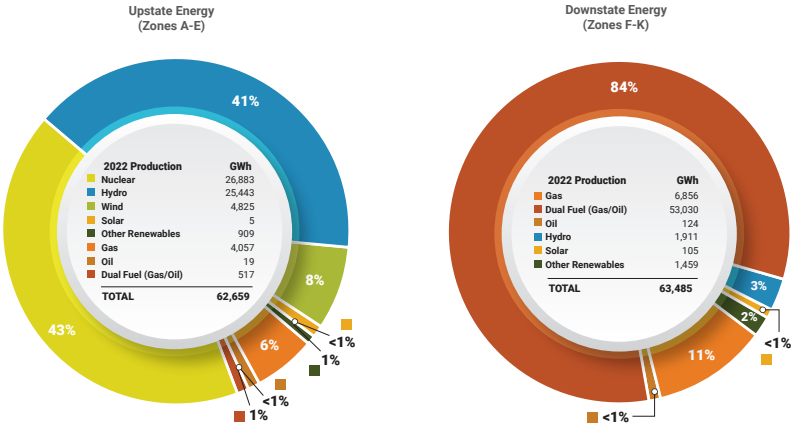
A power grid is a series of energy generators, substations, high-voltage transmission lines, local distribution lines, people, and buildings that either generate, move, or consume electricity. Information about New York's real-time electric power generation and consumption can be accessed at nyiso.com.



Why is Energetic's target 16 GW?

The UN defines 2,000 watts per person as a sustainable level of power consumption. For 8 million New Yorkers, that translates to 16 GW of power. Interestingly, 16 GW is more electricity than New York City has ever needed, and yet this target also assumes a significant reduction in power demand through behavioral change and energy efficiency. How is this possible?

(Remember also that there are 3 million more people on Long Island, a region you do not power in the game. The residents of Long Island would need 6 additional gigawatts if aiming for the 2000 watt per person target.)



In 2022, NYC's power grid (listed as 'Downstate NY') was 95% fossil fuel.
https://www.nyiso.com/power-trends

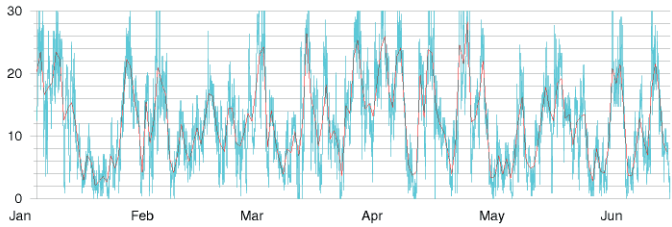
Electricity is just one type of power. Today, we use other forms to heat our homes and drive our cars, among other things. In a decarbonized society, everything that can be electrified will be, because making zero-carbon electricity is easier than making zero-carbon fuel.

Today, New York City's electricity consumption peaks at about 12-13 GW on the hottest days of the summer. When we have "electrified our lives," this number will be larger, potentially significantly larger. Various other societal changes are necessary to ensure we reduce average power consumption. Happily, many of these adjustments involve co-benefits: for instance, less money spent on electricity due to high-efficiency technologies, a four (or three) day work week, more time for leisure and social gatherings, more nature in cities, easier and safer ways to walk and bicycle, and healthier living overall.

What is a capacity factor?

Power capacity conventions for renewable power sources are often very misleading. From a 6 MW wind turbine, for example, you might reasonably expect an average power generation of 6 MW. And the energy generated in an hour? We just covered this! 6 MWh.

Unfortunately, 6 MW is the power that the wind turbine produces if operating at peak production. In real life, wind output looks like this:



Above: Cambridge daily (red) and half-hourly (blue) mean wind speed in meters per second. Source: Sustainable Energy Without the Hot Air by David MacKay.

Wind turbines often receive wind speeds too low to maximize output, and solar panels receive no sunlight at least half of the time. The ratio of the amount of energy you actually generate to the amount it was possible to generate is called the capacity factor (or load factor).

In Energetic, we assume average capacity factors of 25% for Solar (with trackers to orient the array towards the sun) and 50% for Wind. Playing a 1 GW Energetic Wind piece, therefore, means building enough turbines to equal 2 GW nameplate capacity. Playing 250 MW (1/4 GW) of Solar means building 1000 MW of panels.

Capacity factors are neither universal nor constant, so reporting the nameplate capacity of Wind and Solar minimizes inaccuracy. Unfortunately, it does so at the expense of clarity. Readers should be wary of the nameplate power generation cited for renewable sources, as this is often 2-4x greater than what actually gets produced.

What is peak demand?

In July, 2013, a 6 day heat wave reaching a high of 99˚ led to New York City's record for power demand, 13.2 GW. But once the city switches entirely to electric heat pumps for winter heating, the peak demand in winter will be even more. Urban Green Council has modeled NYC's power demand for an electrified city, shown on the following graphs. Even though heat pumps are miraculously efficient, winter peak demand may be as high as 22 GW unless steps are taken to better insulate buildings and reduce demand in other areas, bringing demand down to 16 GW. In the future, New York City's population may increase as migrants arrive from other regions impacted by climate change; this can increase New York's energy demand as well.

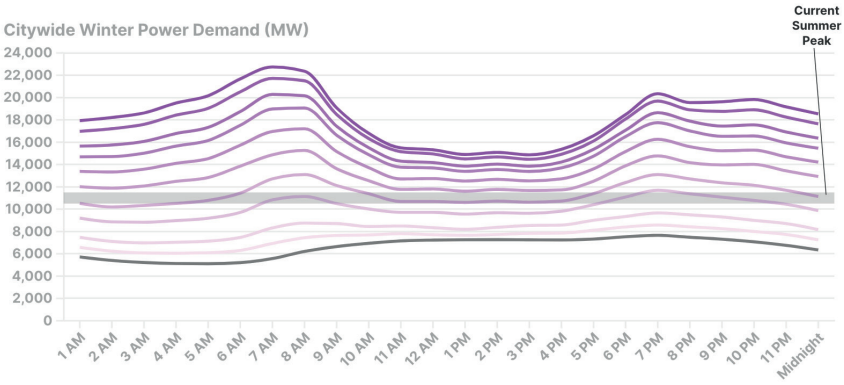
New York breaks peak power usage record in heat wave, Reuters,

Projected Citywide Power Demand by Scenario

Winter peak demand rises incrementally as heat pumps are installed across NYC. Early electrification may only integrate energy efficiency upgrades (S2), but smart electrification that includes demand flexibility measures as well (S4) will be required to keep peaks below 16 GW

Choose a scenario: S1 - Electrification Only

Percent Citywide Electrification: 10% 20% 30% 40% 50% 60% 70% 80% 90% 100% No Electrification

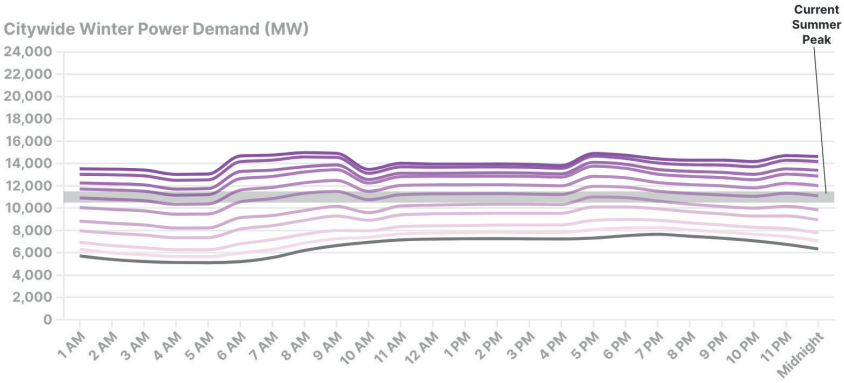


Projected Citywide Power Demand by Scenario

Winter peak demand rises incrementally as heat pumps are installed across NYC. Early electrification may only integrate energy efficiency upgrades (S2), but smart electrification that includes demand flexibility measures as well (S4) will be required to keep peaks below 16 GW

Choose a scenario: S4 - Electrification + Efficiency + Demand Flexibility

Percent Citywide Electrification: 10% 20% 30% 40% 50% 60% 70% 80% 90% 100% No Electrification



Grid Ready: Powering NYC's All-Electric Buildings, Urban Green Council, 12/2021

Game Terms

What is Grid Stability?

The capability to match electricity supply and demand is what is meant by 'grid stability'—can we be confident we'll have power when we need it? Intermittent sources, like Wind and Solar, decrease stability, and we must build Pumped Hydro or H2 Storage to counteract this variability. "On-demand" sources, like Advanced Nuclear and Advanced Natural Gas with CCS, add stability.

10 9 8 7 6 5 4 3 2 1

Above: Energetic's grid stability tracker. Low stability subjects your grid to blackouts. Variable power sources decrease stability, and Storage increases it.

What is Public Opinion?

Public opinion is a measure of citizens' aggregate support or opposition to game actions and events. As Rhiana Gunn-Wright, crafter of the Green New Deal, once said, "Things move at the speed of trust." An actively consenting public is essential if we are to build our decarbonized grid in time to meet the goals of the Paris Agreement (see page 35, Percent for Climate).

1 2 3 4 5 6 7 8 9 10

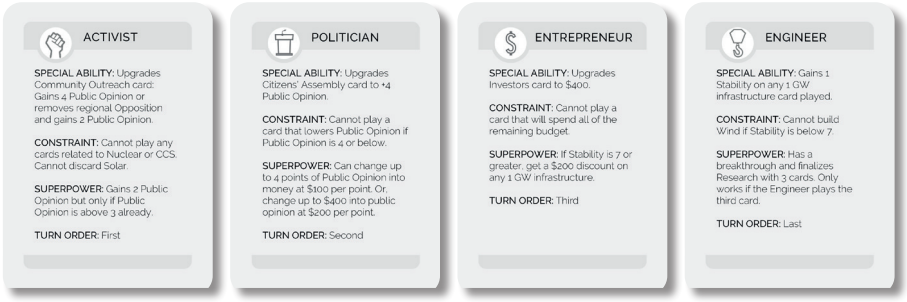
Above: Energetic's public opinion tracker. Game actions increase or cost public opinion, which determines your odds in an election.

What are Energy Bucks?

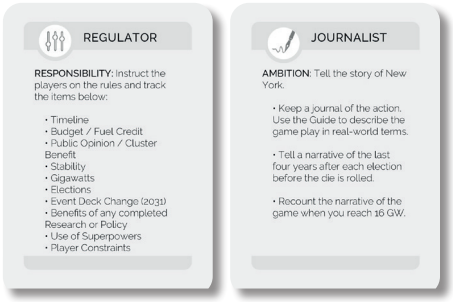
One Energy Buck is equivalent to 10 million dollars, so $100 Energy Bucks is $1 Billion. Game costs are pegged to real data and are justified in this guide.

Role Cards & Scales

Main Roles

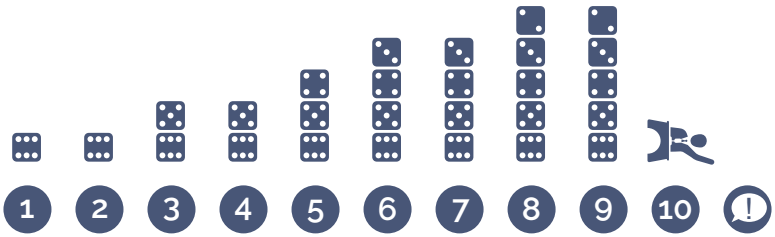


Optional Roles



Activist controls the GW scale.

Politician controls Public Opinion.

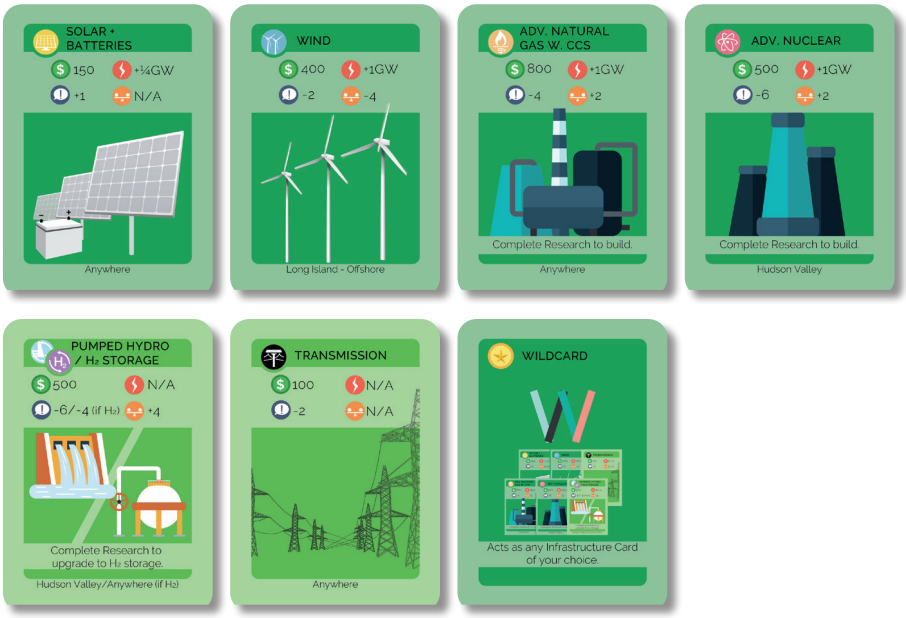


Entrepreneur controls Timeline.

Engineer controls Stability.

Action Deck

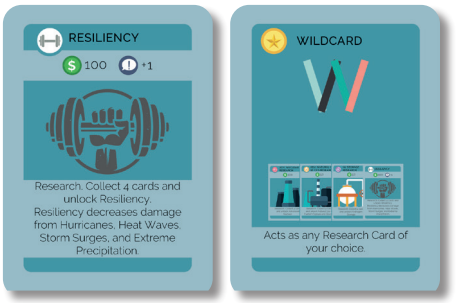
Infrastructure Cards



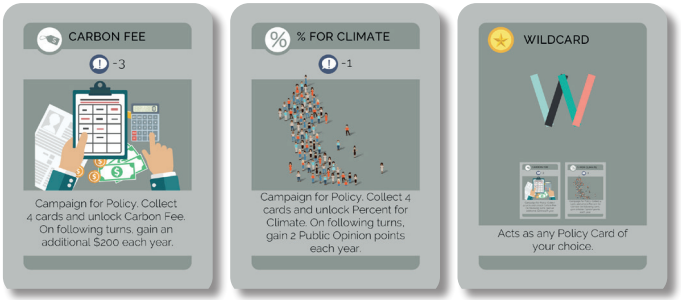
Cost	$100	$150	**$400**	**$500**	**$500**	**$800**	**$500**
GW Added	–	+¼	+1	–	–	+1	+1
Stability	–	–	**-4**	**+4**	**+4**	+2	+2
Public Opinion	-2	+1	-2	**-6**	**-4**	**-4**	**-6**

Campaign Cards

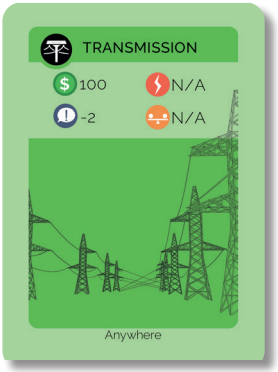
Research Cards



Policy Cards



Transmission



A Transmission line carries electricity over long distances. It is what transports the power from the source, like a solar farm, first to smaller distribution lines and then eventually into our homes. Transmission lines carry high-voltage electricity because high-voltage can be transported more efficiently. But we use low-voltage electricity in homes and businesses, so we need transformers to step up and then back down voltages on either side of the transmission lines.

Why does it not add GW?

Transmission lines do not create power. They simply carry it from one place to another. They actually lose a little energy, so it is more efficient to generate power close to where it will be used. Transmission losses account for about 5% of electricity use in the US.

Why no impact on Grid Stability?

Transmission lines do not affect power generation or demand. Transmission forms the skeleton of the grid, which is made more stable by the ability to match supply and demand at all moments.

Why -2 public opinion?

Transmission lines can cut through natural landscapes or communities, and construction and repair can be disruptive. Broken transmission lines can cause power outages and fires. After a finding that its broken transmission lines started the Camp Fire in California, in August 2019 PG&E warned that it planned to intentionally cut power for up to a week during periods of elevated fire risk. Almost all the major transmission initiatives in the eastern US, including those reproduced on the game board, face public opposition.

Why do they cost $100 Energy Bucks?

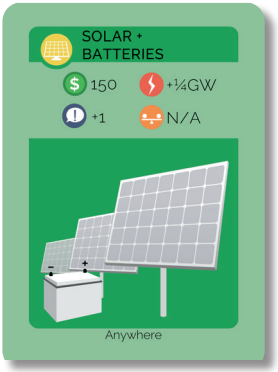
As an example, the Champlain Hudson Power Express (CHPE) is a planned high-voltage direct current (HVDC) transmission project linking the Quebec area to the NYC neighborhood of Astoria, Queens. The line should be complete in 2026, bringing 1 GW of power to NYC. The cost is projected at $2.2B for the section in NY, matching the $200 Energy Bucks in Energetic for two Transmission pieces providing 1 GW on the board.

What is a real world example?

All electricity is transmitted via transmission lines. In NYC, they tend to be below ground. However, in the suburbs or the countryside, one can often see transmission lines by the side of the road.

Left: Most U.S. transmission lines and substations were constructed more than 40 years ago and are based on 1950s technology.

Solar + Batteries



In Energetic, Solar + Batteries refers to the direct conversion of sunlight into electricity through photovoltaic (PV) cells, paired with lithium-ion batteries for short-time-scale storage. Recently, the costs of PV Solar and lithium-ion batteries have plunged, leading to surges in development.

"For the first time in September 2022, the United States had more solar-generated electricity than hydroelectric generation on a monthly basis, according to our Electric Power Monthly."

EIA expects U.S. annual solar electricity generation to surpass hydropower in 2024, EIA, 11/7/2023

Why does it add 1/4 GW?

In order to provide 250 MW (1/4 GW) of power to the grid, we are actually building four times that amount of nameplate capacity—1000 MW—and assuming an average capacity factor of 25% (see page 8, What is a capacity factor?). This means that every Solar Piece you place on the board represents a collection of infrastructure spanning 6,000 acres, an area of land just under half the size of Manhattan, and one of the largest solar farms ever built.

Why no impact on Grid Stability?

Despite Solar's intermittency, when played, it has no effect on Energetic's grid stability tracker. This is because Solar in Energetic includes six hours of lithium-ion battery storage, which accounts for daily fluctuations in available power. Batteries are good for short-term variability but struggle with retaining power over long periods. The Cloudy Days Random Event decreases stability by 2 points for every full GW of Solar Power built.

Why +1 public opinion?

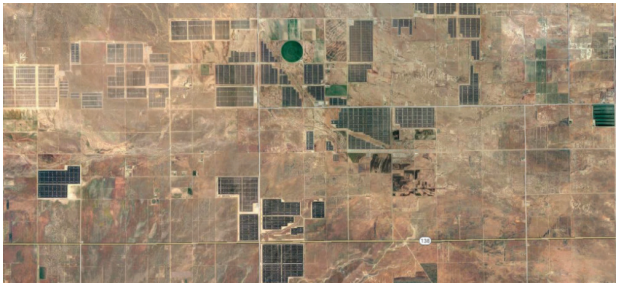
A 2016 Pew Research poll found that 89% of Americans supported expanding solar power. This excitement may be somewhat tempered when Solar is commissioned in real communities, and truly vast pieces of infrastructure will actually have to go somewhere. Generally, however, Solar enjoys near-universal support, and the jobs created by building and operating these farms may increase its popularity.

Why does it cost $150 Energy Bucks?

We need four things: panels, land, batteries, and trackers. Summing what each of these components will cost for every real watt, we get an estimate of about $5/W. It costs $5 for 1 W—since we want 250 MW, we should multiply this number by 250 million. This suggests a cost of between $1 – 1.5 billion. Let's round up and call it $1.5 billion: that's $150 Energy Bucks!

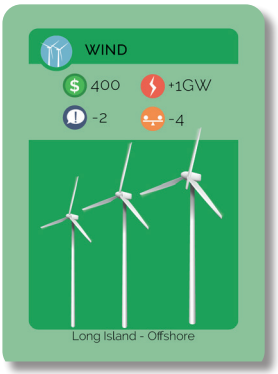
What is a real world example?

The Solar Star farm in Rosamund, CA has a nominal capacity of 579 MW. With trackers, its capacity factor across 2017-2018 was 33.2%. In New York State, which is less sunny year round, the average performance of utility solar in the state is below 25%.



Left: Solar Star Farm as seen from Google Earth. The width of this photo is about 14 miles. Each Solar Piece in Energetic is a farm 30% bigger than this.

Wind



Wind turbines spin a generator to create electricity. In Energetic, we build Offshore Wind farms off the southern coast of Long Island. Offshore Wind takes advantage of higher wind speeds to create more power. The 2.6 GW Coastal Virginia Offshore Wind project, Dominion Wind, will be one of the largest Offshore Wind farms in the world. It will include 176 14 MW wind turbines, and at 50% capacity factor the project will be slightly larger than a 1 GW Wind piece in Energetic.

Why does it add 1 GW?

Offshore Wind has a capacity factor of around 45-55%, so to reach 1 real GW, we need to build 2 GW of nameplate capacity (see page 8, What is a capacity factor?). Each Wind piece represents an offshore farm larger than any that yet exists. If we use GE's Haliade-X 12 MW turbines, then we need 170 turbines to generate 1 real GW (remember, that's 2 GW of nameplate capacity). Each 12 MW turbine is 850 feet tall, almost as tall as the Eiffel Tower, and turbines must be spaced one mile apart to minimize turbulence. To not be visible from the Long Island coast, the farm would need to be built 40 miles offshore.

Why -4 Grid Stability?

Wind Power is inconsistent. With Wind, there are two types of variability: short-term "slews" and longer-term "lulls." Though they will present some new challenges, short-term slews involve handling adjustments to the power supply on the same scale as the morning ramp-up in energy use grid operators deal with on a daily basis. Long-term lulls present a distinctly new problem, however, and as you'll see, the random event Wind Lull can have a catastrophic effect on a grid that is too dependent on Wind Power not matched with Storage (see pages 26-27, Pumped Hydro and pages 28-29, H2 Storage).

Why -2 public opinion?

"I'm more worried about what these plans [for the proposed London Array wind farm] will do to this landscape and our way of life than I ever was about a Nazi invasion on the beach." – resident of Graveney, England, quoted in David MacKay's Sustainable Energy Without the Hot Air. Wind farms alter landscapes and views which can generate local backlash. Also, they sometimes kill birds, though fewer than cats, glass windows, or the rapidly changing climate, which might cause 30% of bird species to go extinct before 2100.

Why does it cost $400 Energy Bucks?

From 2013 to 2018, the financing cost of Offshore Wind in Europe fell by over 40%. Thanks to economies of scale and technological advances, Offshore Wind in Germany cost an average of $1.80 per watt in 2018. For our 2 GW of rated power, that would mean $3.6 billion. Let's round up and call it $4 billion: that's $400 Energy Bucks! Vineyard Wind, one of the first offshore wind projects in the US, is priced closer to $500 Energy Bucks, and Dominion Wind is more expensive yet, but as the supply chain grows for offshore wind prices should decline.

What is a real world example?

An example of a large Wind farm is the Walney Extension in the Irish Sea, with a nameplate capacity of 659 MW and a capacity factor of 42% (so, 0.3 GW of real production—about 1/3 of one Wind Piece).

Left: The Walney Extension Offshore Wind farm in the Irish Sea. The farm's 87 wind turbines are each around 700 feet tall and together cover 55 square miles. (Photo: Ørsted)

Adv. Natural Gas w. CCS

In 2018, Natural Gas plants produced 35% of the electricity used in the United States. Unfortunately, burning natural gas emits carbon dioxide, and leaking natural gas releases methane, an even more dangerous greenhouse gas. Advanced Natural Gas with CCS (Carbon Capture and Storage/ Sequestration) refers to a power plant that captures CO2 and securely stores it before it can enter the atmosphere. Though carbon capture technology is included in most decarbonization pathways that limit warming to 2C or less, it remains unproven at scale and prohibitively expensive in financial and energy costs. Energetic players must complete Research before building this infrastructure.

Why does it add 1 GW?

Unlike with Solar or Wind, Adv. Natural Gas with CCS does not need to be discounted by a capacity factor, and 1 GW of rated production could equal 1 GW of real production if the plant were turned on all the time. Adv. Natural Gas with CCS harnesses the same power potential as natural gas without CCS (minus the power required to capture, deliver, and store the fuel's released carbon, which may be substantial).

Why +2 Grid Stability?

In a system with increasing variability from Wind and Solar, Adv. Natural Gas with CCS can contribute to grid reliability in a variety of ways, including dispatchability (ability to adjust to consumption demands), and fast start time and ramp-up rates.

Why -4 public opinion?

Public support for Natural Gas is declining due to increased awareness of environmental concerns. Though a Natural Gas plant utilizing CCS technology would not contribute to global heating through carbon emissions (assuming the captured CO2 does not leak back into the atmosphere), it would still have other negative impacts on people's quality of life, health, open spaces, and drinking water.

Why does it cost $800 Energy Bucks?

With CCS still in the RD&D phase, there are barriers in time and investment that will determine its viability. The NREL estimates capital expenditures for natural gas combined cycle plants with carbon capture to be just over $2/W. This does not include the significant costs of delivery or storage, nor monitoring to ensure the captured gas doesn't escape. Power plants with CO2 capture under development cost closer to $10/W, although these are mainly coal plants. Also, while Wind and Solar are essentially zero marginal cost, Natural Gas plants must continuously buy fuel. We chose $8/W as an estimate of where costs might emerge after the RD&D phase—for 1 GW, that's $800 Energy Bucks.

What is a real world example?

Operating from 1991 to 2005, the 40 MW Bellingham natural gas combined cycle (NGCC) power plant in Massachusetts captured 85-95% of carbon emissions. The carbon emissions were then purified and used within the food processing industry.

A natural gas plant with CCS is currently being tested in La Porte, Texas: Turns Out, NET Power Hasn't Delivered Net Power, Heatmap News, 5/6/2024

Advanced Nuclear

Nuclear power plants use a process called fission to split the nucleus of an atom, releasing heat energy to make steam that rotates a turbine. Advanced Nuclear refers to the next generation of reactors currently in development, which will be safer, potentially smaller, and more versatile, though there is uncertainty about what this RD&D phase will produce. These may take the form of Small Modular Reactors (SMRs), which offer a host of financial and safety advantages.

Why does it add 1 GW?

SMRs range in capacity up to 300 MW, so a Nuclear Piece in Energetic represents the combined output of several smaller reactors. The modular design lets reactors be produced in a factory environment and shipped to the point of use. Along with other factors, this allows for greater site flexibility and it is hoped that SMRs will become attractive options for direct replacement of fossil fuel infrastructure.

Why +2 Grid Stability?

Nuclear power is dispatchable, or "on-demand." Nuclear has typically provided base-load power, running constantly. SMRs have a load-following design that can match production to demand.

Right: Indian Point nuclear power plant, completed in 1968, provided about 25% of the city's electricity until it was shut down in 2021.

Why -6 public opinion?

Nuclear technology was first introduced to the general public as a tool for mass destruction when the US dropped atomic bombs on Hiroshima and Nagasaki. The distrust of nuclear power is furthered by fears of nuclear plant meltdowns, such as the disaster at Chernobyl in 1986. Nuclear power also creates dangerous waste. Because of this, it has frightening associations in the public consciousness, and many environmental advocates oppose its expansion.

Why does it cost $500 Energy Bucks?

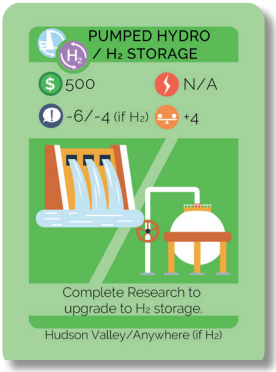
Since Advanced Nuclear reactors are still in the process of being researched, designed, and demonstrated, there is limited cost data available. Median estimates for a 225 MW reactor range from $3,200 to $7,100/kWe. NuScale Power estimates their SMRs cost between $4,000 – $5,000/kW. Let's use $5,000 / kW, so $5 billion for 1 GW - that's $500 Energy Bucks! In 2023, NuScale's first contract to build reactors was canceled due to rising costs, but 22 countries have pledged to triple nuclear power by 2050.

22 Countries Pledge to Triple Nuclear Capacity in Push to Cut Fossil Fuels, NYT, 12/2/2023

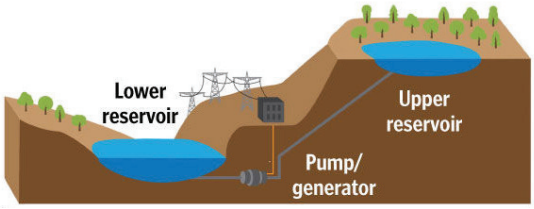
What is a real world example?

France has the world's most expanded nuclear capacity, relying on the power source for nearly three-quarters of its electricity in 2017. Sweden and the UK also rely on nuclear, and Sweden (pop. 10M) has announced a goal of two new reactors by 2035, and 10 reactors by 2045. In New York State, Indian Point Energy Center was a three-unit nuclear power plant with a 2 GW capacity; it shut down in 2021, taking with it almost all of NYC's zero-carbon power. In 2023, downstate NYC relied on gas for power generation, while upstate New York had substantial zero-carbon sources, including hydroelectric power and nuclear power.

Pumped Hydro



Pumped-Storage Hydropower, or Pumped Hydro, is a large-scale energy storage method that utilizes two water reserves at different elevations. When power generation exceeds demand, water is pumped to a higher elevation, which stores gravitational potential energy. Then, when demand exceeds generation, the water is allowed to fall back down, revolving a turbine to turn potential energy back into electricity.



Left: A cartoon drawing of a Pumped Hydro facility. Water pumped to the upper reservoir stores energy until needed. Significant storage requires steep elevation gradients and huge amounts of water.

Why does it not add GW?

Pumped Hydro facilities store energy generated by other sources, but are not a power source themselves. This 'load balancing' is essential to ensure that we are able to access power when we need it. In fact, it is probably more useful to think of Wind Power and Storage as two pieces of a coupled system, both equally essential.

Why +4 Grid Stability?

In Energetic, Pumped Hydro is designed to pair with Wind, which is why building Pumped Hydro both adds back the 4 stability points that Wind subtracts from Energetic's Stability Tracker and immunizes the grid from Wind Lull Events. Four-day lulls, though infrequent, are not rare. Losing a 1 GW Wind Piece for four days would require an energy storage capacity of 96 GWh—120 times larger than the total storage capacity installed in the US in 2018.

Why -6 public opinion?

Pumped Hydro facilities are massive structures that significantly impact natural water features and landscapes and will likely encounter stiff resistance. In March, 2020, a developer named Premium Energy Holdings proposed a pumped hydro facility drawing from the Ashokan Reservoir, part of NYC's drinking water supply in the Catskills north of NYC. Faced with immediate public opposition, the proposal was withdrawn a month later.

Why does it cost $500 Energy Bucks?

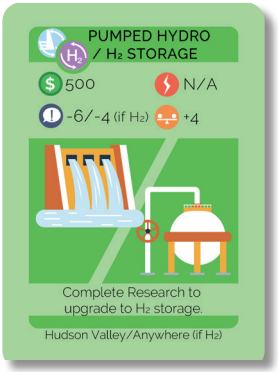
To protect our grid from Wind Lulls, we need a power capacity of 1 GW and a reservoir that can run for 96 hours. Cost is largely a function of power capacity since that is how large the pumping mechanism between the two reservoirs must be (while the size of the reservoir determines the amount of energy that can be stored). Pumped Hydro costs between $1,000 – 4,500 per kW. Our plants store more energy than any currently existing, so let's take the upper estimate and then round up. That's $5 billion, so $500 Energy Bucks!

What is a real world example?

The Bath County Pumped Storage Station in Virginia is the largest in the world, with a power capacity of 3 GW and an energy storage capacity of 24 GWh. Its upper reservoir is 1,260 feet above the lower reservoir with a surface area of 265 acres and a water depth of 135 feet.

Left: Bath County Pumped Storage Station's upper reservoir, which holds as much water as Canadice Lake, the smallest of New York's Finger Lakes. Each Pumped Hydro piece in Energetic holds four times as much energy.

H2 Storage



H2 Storage uses excess power to feed an electrolyzer, which extracts Hydrogen gas from water. Hydrogen gas, held in large tanks or underground caverns until needed, can be used in a variety of ways. When there is insufficient power generation, the gas can be turned back into electricity with a fuel cell or turbine.. Hydrogen gas can also be used as fuel for transport and burned to create the high levels of heat needed for heavy industries like steel and cement manufacturing.

Why does it not add GW?

H2 Storage does not generate new power but stores large amounts of energy so that we are able to respond to changes in power demand. As mentioned before, because of the huge variability of Wind, it is useful to think of Wind and Storage as two pieces of a coupled system, both equally essential. As a storage method, Hydrogen gas has fewer geographic constraints than Pumped Hydro and is more versatile, since it can be turned back into electricity or burned as a fuel.

Why +4 Grid Stability?

Like Pumped Hydro, building H2 Storage counteracts the stability hit that comes from building Wind power and protects the grid from Wind Lull Events. A four-day lull requires 96 GWh of power to be stored. Unfortunately, turning Hydrogen back into electricity with a fuel cell involves round-trip efficiency losses of 45–50%.

Why -4 public opinion?

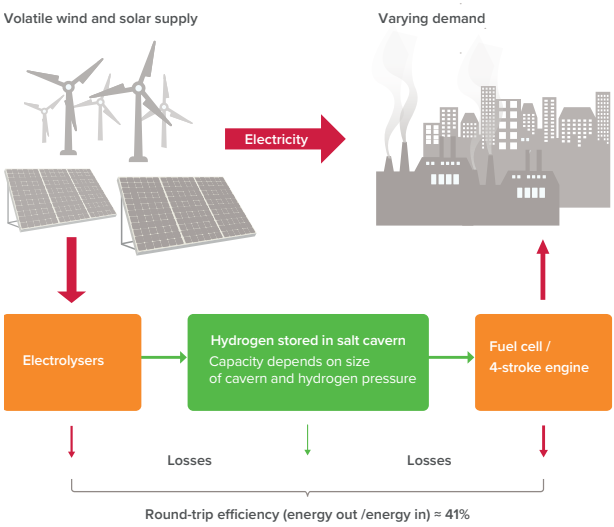
H2 Storage is still developing as a technology, and there is limited opinion data available. Shifting to Hydrogen would be a large change for many people and some resistance can be expected. Safety is a concern, as the wrong conditions can lead to an explosion. Also, storage units and piping may be large and obtrusive.

Why does it cost $500 Energy Bucks?

A 2016 report estimated the system cost of H2 Storage at $20 – 25 per kWh, which translates to $2.4 – 3 billion for our desired size of 120 GWh (to make up for a five-day Wind Lull Event). Once the facility is built the electrolysis process itself may be cheap, using hours of surplus Wind or Solar power to make H2. At a production goal of $1.50 per kg, and 30 kg of H2 required to produce a MWh of power, then one MWh of H2 would cost $45. Note that to build the industry, the UK is currently subsidizing green H2 with a much higher price of $12/kg. Storage and distribution require large-scale development, though existing natural gas pipelines might be re-used to transport Hydrogen. Let's conservatively estimate $5B for all costs—that's $500 Energy Bucks!

What is a real world example?

The UK plans to add enormous H2 capacity to provide up to several weeks of energy storage, as shown in a 2023 report from the Royal Society. The 2023 report estimates UK storage needs are 1000x the current national pumped hydro capacity.



"The fuel cells and / or 4-stroke engines that convert hydrogen to electricity must be sized to be able to meet all demand when the wind is not blowing and the sun is not shining. Within limits, demand can be met with a relatively small total storage capacity charged by very powerful electrolyzers (which convert electricity to hydrogen), or a larger capacity charged by less powerful electrolyzers."

The Royal Society Large-scale electricity storage report, Royal Society, 9/8/2023

Citizens' Assembly

A citizens' assembly is a method of governance that brings together randomly selected citizens in a mix representative of the full population. This sample of citizens then learns from expert sources about a social problem, or proposed policy. They discuss it together and consider solutions. The citizen group then makes recommendations to policymakers or the public, offering a balanced and informed perspective of what a mix of citizens think when given time and resources to study and issue.

In 2019, French president Emmanuel Macron called a Citizen's Assembly on climate after the Yellow Vest riots, which were protesting a carbon fee on fuel, spread across France. Ireland and the UK have also held Citizens' Assemblies on climate change.

Macron's 'direct democracy' to be tested as citizens' panel on climate wraps up. France 24, 01/03/2021

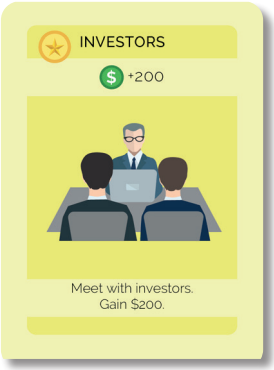
In Energetic the Politician upgrades Citizens' Assembly card to +4 Public Opinion.

Right: Citizen's Assembly on climate in France after the Yellow Vest riots

Community Outreach

Community outreach is a way to engage with the people who will be affected by new infrastructure. Public meetings are organized and plans shared to gather feedback and address concerns, and information provided through newsletters, websites, and social media. Plans may be adjusted based on community input. This open communication helps build trust and cooperation, ensuring that the new infrastructure benefits the community while minimizing disruptions. It's a way to involve the community in decision-making and make the process more inclusive.
In Energetic, the Activist upgrades the Community Outreach card to either gain 4 Public Opinion or remove regional Opposition and gains 2 Public Opinion.

Investors



Green investment directs financial resources toward projects and initiatives that promote environmental sustainability and reduce carbon emissions, such as renewable energy, energy efficiency, and clean transportation. These investments are crucial for transitioning to a low-carbon economy and mitigating climate change.
In Energetic, the Entrepreneur upgrades Investors card to $400.

"From 2019 to 2023, clean energy investment increased nearly 50%, reaching USD 1.8 trillion in 2023 and growing at around 10% per year across this period."

IEA World Energy Investment 2023

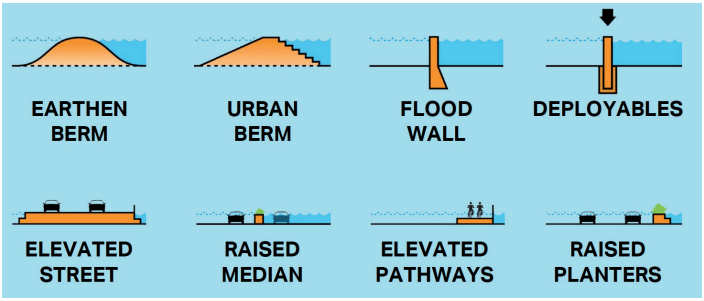
Resiliency

"Resiliency" refers to the ability of communities to withstand and recover from climate impacts like Hurricanes, Heat Waves, Storm Surges, and Extreme Precipitation.

Four cards unlock Resiliency and cost 100 Energy Bucks ($1B) each. In the real world, NYC is completing the East Side Coastal Resiliency project on the East River as protection against Storm Surges; this single project is budgeted at $1.3B. A full coastal protection plan for NYC is currently budgeted at 5200 Energy Bucks ($52B), with cost shared between federal, state and city budgets. If Percent for Climate (p. 35) were enacted, a $52B Resiliency budget would unlock $520M of climate education funding, enough for ten years of climate education in NYC.

"The new Army Corps proposal would include a series of sea gates — movable walls to be closed only for major storms — that would block waterways around Brooklyn, Queens, Staten Island and New Jersey, along with 31 miles of land-based levees, elevated shorelines and sea walls. It would require approval from the state and local governments that would foot the rest of the bill."

A $52 Billion Proposal Aims to Protect New York Harbor From Storm Surges, NYT, 9/26/2022



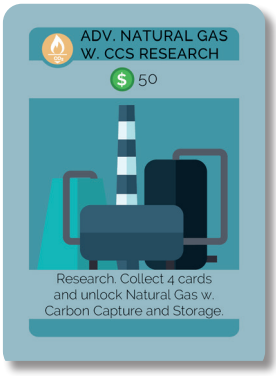
Left: Different types of Coastal Resiliency Infrastructure.

Energy Infrastructure

To build Hydrogen storage, Advanced Nuclear, and Advanced Natural Gas with Carbon Capture and Storage, collect 4 cards in the Research slots.

In Energetic, the Activist cannot play any cards related to Nuclear, including Adv. Nuclear Research.

The Engineer can have a breakthrough and finalize any Research with 3 cards by playing the third card.



Carbon Fee

A Carbon Fee puts a price on carbon in an attempt to account for the negative externality of emitting greenhouse gases and to incentivize emission reduction and development of alternative technology. It is the preferred climate policy of nearly all economists and a classic example of a Pigouvian tax. Recent research has found fossil fuel extraction to be extremely inelastic and insensitive to market pressures. A working paper from the National Bureau of Economic Research found that even a price of $200 per ton (most carbon fees are in the range of $40/ton) would reduce emissions by 2%.

"The BC experience also offers cautionary lessons about the politics of carbon taxes. Public misunderstanding of how environmental taxation works, combined with the visibility of costs and lower visibility of benefits, renders carbon taxes ripe for populist attacks."

Lessons from British Columbia's carbon tax. Policy Options, 7/2019

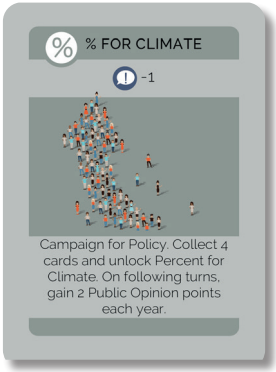
Why -3 public opinion during passage?

Carbon Fees consistently rank last in public support when climate policies are polled. Though it is no panacea, a Carbon Fee could certainly be an important piece of our response to the climate crisis if it were able to be enacted. Doing so politically, however, has proven exceedingly difficult. The Canadian province of British Columbia has had a carbon tax since 2008.

Why +$200 Energy Bucks to annual budget?

Carbon pricing creates a revenue stream that can be reinvested to accelerate the energy transition. In 2016, New York City emitted 52 million metric tons of CO2-e. At $40/ton, this would create just over $2 billion in revenue, which corresponds to $200 Energy Bucks. Though emissions will fall as you continue to build a carbon-neutral power grid, most carbon fee schemes involve increasing the price per ton over time.

Percent for Climate



Based on the existing NYC law Percent for Art, Percent for Climate would set aside one percent of any government-backed infrastructure projects to create a fund for climate education, outreach, and public consultation, allowing New York to teach itself about the climate crisis and decide we can do in response. As you play Energetic, you'll see that the coming months, years, and decades must be full of change—large, visible, community-affecting change. This will not be possible without an actively consenting public.

"The U.S. public is under-prepared and insufficiently educated to fully carry out the work required of them for the nation to achieve deep decarbonization or to participate and engage effectively in deep decarbonization planning processes."

National Academies of Sciences, Engineering, and Medicine. 2023. Accelerating Decarbonization in the United States: Technology, Policy, and Societal Dimensions.

The challenges of rapidly decarbonizing and adapting to the climate impacts we have already locked in will involve extremely difficult decisions. Citizens do not need to be circumvented; they need to be entrusted with knowledge and decision-making power. We must actively rebuild trust in a society in which there is now very little.

Why -1 public opinion during passage?

Passing any legislation is difficult, and this bill would (nominally) increase government spending.

Why +2 public opinion/year?

An informed public given ownership over this transition will support its (which is to say, their own) efforts more. The extension of trust significantly increases public engagement. Evidence of this is clear in democratic experiments like Citizens' Assemblies.

Random Event Deck

Weather

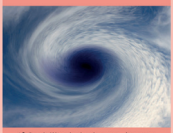
HEAT WAVE

There is a high demand for air conditioning. If Stability is below 3, blackouts occur; lose 4 Public Opinion. If Stability is 3 or above, lose 2. If Resiliency is unlocked, lose 1 Public Opinion point less than the above.

DROUGHT

Lose 2 Stability for every Pumped Hydro storage or Nuclear facility built.

HURRICANE



If Stability is below 5, lose 5 Public Opinion. Otherwise, lose 3. If Resiliency is NOT unlocked, lose $200, lose a Long Island Transmission line, and the Politician is muted next turn.

STORM SURGE

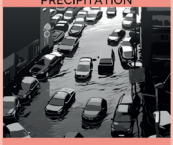
Lose 2 Public Opinion. If it's:
- 2030-2040, lose $300.
- 2041-2050, lose $400.

If Resiliency is unlocked, losses are cut in half.

WILDFIRE SMOKE

Lose 1 Stability for every full GW of Solar. Roll for Public Opinion:
- 6, gain 2 Public Opinion.
- 4- 5, gain 1 Public Opinion.
- 1 - 3, no effect.

EXTREME PRECIPITATION



Lose 1 Public Opinion and $50. If Resiliency is unlocked, there is no loss of Public Opinion or money.

Public Health

MOSQUITOES MOVE NORTH

Mosquito-borne diseases spread. Lose 2 Public Opinion. The Politician is muted next turn.

MIGRANT CRISIS

Lose 2 Public Opinion. The Politician is muted next turn.

AIR POLLUTION

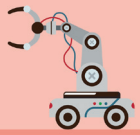
If you haven't built 8GW of zero carbon power yet, an air quality health advisory is issued. Lose 2 Public Opinion.

FOOD SHOCK

Lose 2 Public Opinion. The Politician is muted next turn.

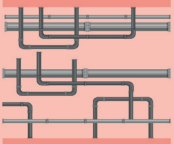
Energy and Technology

TECH ADVANCEMENT



Electricity demand has fallen because of efficiency research. Get a bonus 1 GW!

METHANE LEAKAGE



Lose 2 Public Opinion if you have built Adv. Natural Gas w. CCS.

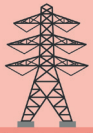
RESEARCH FAILURE

Lose a card on every Research project that you haven't yet unlocked. Does not apply to Resilience. Completed Research is unaffected.

NUCLEAR ACCIDENT

If you've built Nuclear, roll the die.
- 1 - 3: Lose 2 Public Opinion. No new Nuclear for 2 years.
- 4 - 6: Lose 6 Public Opinion. No new Nuclear for 8 years.

TRANSMISSION LINE FAILURE



Spend $200 to fix it or lose a Transmission line of your choice, and lose the GWs you have tied to that line until you reconnect.

BLACKOUT

If Stability is below 5, lose 1 Public Opinion. If Stability is below 2, lose 2 Public Opinion.

CLOUDY DAYS

Lose 2 Stability for every full GW of Solar built.

WIND LULL

Roll the die.
- 1 - 4: The lull lasts 4 days. Lose 1 Stability for every GW of Wind built without storage.
- 5 - 6: The lull lasts 8 days. Lose 2 Stability for every GW of Wind built without storage.

Politics and Economy

CLIMATE MARCH

Everyone is motivated to take action! Gain 3 Public Opinion.

B.A.N.A.N.A.

Build Absolutely Nothing Anywhere Near Anything. Place both Opposition markers. For one turn, you cannot build in the Hudson Valley, on Long Island, or out-of-state Transmission.

UPSTATE OPOSITION

Cannot build in the Hudson Valley; place an Opposition marker. You can undo the Opposition by playing a Community Outreach card.

LONG ISLAND OPPOSITION

Cannot build on Long Island; place an Opposition marker. You can undo the Opposition by playing a Community Outreach card.

ECONOMIC PROSPERITY

This year was a great year for renewable energy investments and renewable jobs are on the rise. Gain $100 and 2 Public Opinion!

ANTI-FRACKING MOBILIZATION

Lose 3 Public Opinion if you have built Adv. Natural Gas w. CCS. Wind does not cost any Public Opinion next turn.

MARKET CRASH

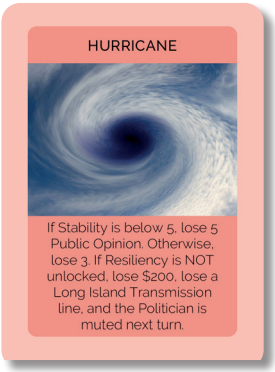
A decline in coastal land values has led to a stock market collapse. Next turn you don't get any money and the Entrepreneur is muted.

Weather

Heat Wave

Heat waves threaten health and, since A/C is very power-intensive, can overwhelm a grid and cause blackouts. If warming is limited to 2˚C, thousands may die from heat waves in northern latitudes every year, and cities in the equatorial band may become uninhabitable, with wet bulb temperatures above the cutoff for human survival. In the worst case scenario (4˚C), the 2003 European heat wave, which killed 2,000 people a day, would be a normal summer.

Brutal heatwaves and submerged cities: what a 3C world would look like, Guardian, 05/11/2024



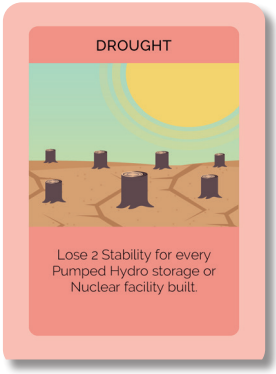
Hurricane

Hurricanes are fueled by warm ocean water, and the oceans are heating up. Warmer air can also hold more moisture. Climate change is also likely to weaken summer ocean currents, which stalls storms above the same patch of land for longer periods. In 2019, Hurricane Dorian sat over Grand Bahama Island and Abaco Islands for three days, unleashing historic destruction.

In the aftermath, the USAID administrator said it looked like "nuclear bombs were dropped." Around 70,000 people were left homeless, approximately 100% of the islands' combined population.

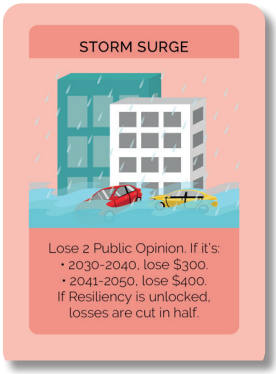
Left: Once, homes. Hundreds remain missing after Dorian.

Right: Dorian refugees were turned away by United States CBP.



Drought

Droughts pose health risks, harm crop growth, and increase wildfire exposure. They also impact Pumped Hydro and Nuclear facilities, both of which rely on large amounts of water. Without dramatic emission reductions, Southern Europe will be in permanent drought worse than the Dust Bowl by 2080. By 2050, freshwater availability in cities will decline by as much as two-thirds. Seasonal melt provides water for 50% of the world—these deposits are dramatically threatened. Right now, many fill the gap with groundwater aquifers that accumulated over millions of years; in coming years, up to twenty cities in India could exhaust their supply.



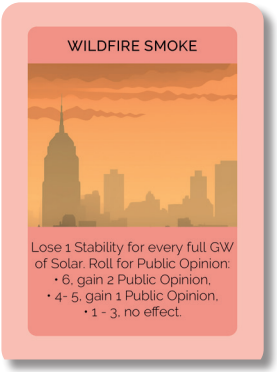
Storm Surge

Storm surge is a rise in sea level primarily caused by water pushed ashore by a storm's winds. Storm surges will grow as storm strength increases and sea levels rise. A small vertical increase in sea level can translate into a very large increase in horizontal reach by storm surge. The 8 inches that sea level had already risen due to climate change extended Hurricane Sandy's reach by 27 square miles.

Left: Chennai, India, pop. 5 million, has run out of water.

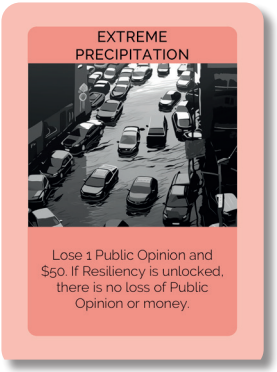
Right: Hurricane Sandy surge. By 2100 these floods will be 17 times more likely.

Weather



Wildfire Smoke

Large wildfires emit vast amounts of smoke, which can impact air quality over thousands of miles. In the summer of 2023 a record-breaking fire season in Canada intensified exposure to harmful particulate matter as far as NYC, posing health risks like respiratory issues and cardiovascular problems.



Extreme Precipitation

Warm air holds more moisture than cold air. In thermodynamics, this is known as the Clausius-Clapeyron relation and explains why rising global temperature leads to more intense and record-breaking rainfall events. Warmer air acts like a sponge, soaking up larger quantities of water. When saturated warm air rises, it cools and condenses to rain. Heavily saturated air can condense into a downpour that overwhelms a city's storm drainage systems and causes floods.

Left: View from DZ BANK AG New York office in NYC, 2023. Photo by Jasmin Wanner

Right: Flash flood in Brooklyn, 2023. Photo by Steve Kastenbaum

An installation ship holds blades and towers ready to be built. Photo: Ørsted.

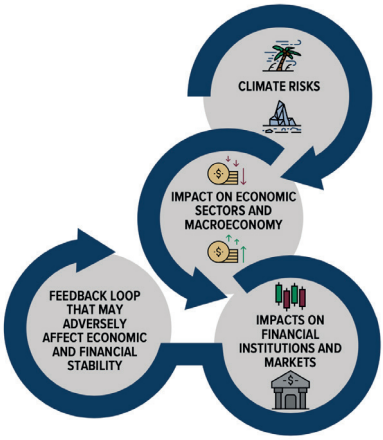
Politics & Economy

Climate March

Public demonstrations demanding climate action have been growing rapidly. Fridays For Future, Extinction Rebellion, and others have brought the urgency of the crisis to the forefront of the public consciousness and turned out huge numbers of protesters. In September 2019, over six million people worldwide took part in a general strike for climate.

Market Crash

The "Carbon Bubble" is the difference between valuations and worth in fossil fuel corporations, climate-harmful industries and vulnerable physical assets. Companies own more fossil fuels than we can burn. Climate action (or decline in the cost of renewables) may make these "stranded assets" suddenly worthless. And the value of coastal real estate drops when extreme climate risks are taken into account. Insurance companies are already retreating from states leading in climate risk, including California and Florida.



"More severe and frequent climate-related events are imposing significant costs on the public and the economy, with economic costs from climate change expected to grow."

Financial Stability Oversight Council Releases 2023 Annual Report, U.S. Department of The Treasury, 12/14/2023

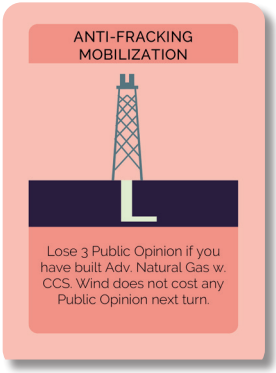
Opposition

Local opposition has killed many infrastructure projects. A 1962 Con Edison plan to build Pumped Hydro on the Hudson River's Storm King mountain was opposed by conservation groups. The "Save Storm King" campaign launched the modern American conservation movement on the ideal of "untouched" nature, which has come in conflict with the need to rapidly build out carbon-neutral infrastructure such as wind power.

Economic Prosperity

Millions of people worldwide are employed by the renewable energy industry. Many Americans' livelihoods, however, are still deeply rooted in the legacy fossil economy. Policy makers are proposing a just transition— targeting communities that are the most vulnerable to climate change and its effects and providing displaced workers income and benefits while they transition to another job.

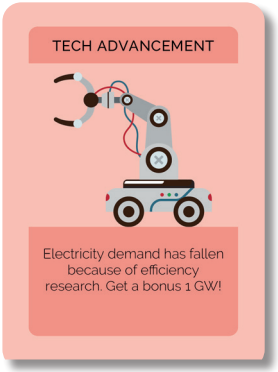
Over 100,000 manufacturing jobs announced since Inflation Reduction Act passed, Renewable Energy World, 05/07/2024



Anti-Fracking Mobilization

Fracking leaks large amounts of methane, a dangerous greenhouse gas. It depletes and contaminates water sources and causes earthquakes. A 2018 study found that children born close to a fracked well were smaller and less healthy. France and Germany have banned fracking.

Energy & Technology



Tech Advancement

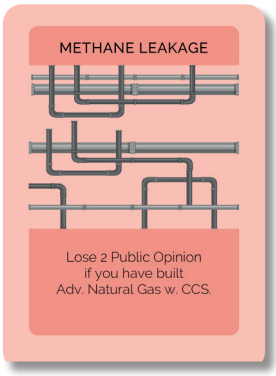
In Energetic, the goal is to create 16 GW of zero carbon power, enough for 2,000 watts per person. The average American lifestyle consumes 4,000 watts; New Yorkers, however, are some of the lowest energy consumers, because of dense housing and mass transit. Behavior change and efficiency are vital to reduce energy demand. LED lights use 85% less power than incandescent bulbs. The development of enzymes to allow for cold-water washing reduced national energy demand by approximately 1%.

Saul Griffith | The Energy Problem(s) [Video @ 51:32]. YouTube

Research Failure

All nuclear power plants in operation today rely on controlled fission—splitting isotopes to release energy. Nuclear fusion, the process that powers the sun, is a reaction in which two atomic nuclei fuse, offering nearly unlimited energy. However, despite many predictions through the years that fusion was just around the corner, the technology has been stuck in the research and development stages for decades. Research on fusion reactors continues to make advances, but it has proven an extremely difficult engineering challenge.

The companies that design advanced fission reactors are also experiencing setbacks due to inflation and the challenging economics of building complex infrastructure.

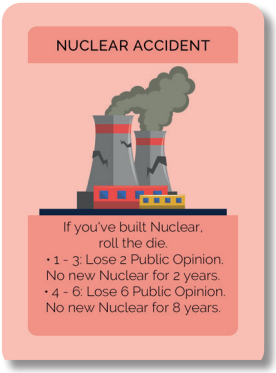


Methane Leakage

Methane levels have risen since 2008 with the expansion of shale gas and oil fracking in the United States. Methane is released during fossil fuel production and transport. It can be leaked accidentally or deliberately "flared" (burned off). Methane dissipates from the atmosphere more quickly than CO2 but has a higher warming effect. The Environmental Defense Fund found that methane emissions from U.S. oil and natural gas production were 60% higher than the federal government's estimates, which might erase natural gas's supposed climate advantage over coal.

"Methane is responsible for around 30% of the rise in global temperatures since the Industrial Revolution"

Global Methane Tracker, IEA, 2024



Nuclear Accident

The Chernobyl disaster in 1986 is considered the worst nuclear accident in history. An explosion exposed the reactor core, releasing about four hundred times more radioactive material than the bombings of Hiroshima and Nagasaki in 1945, leading to radiation poisoning, cancer, and birth defects. Global wind currents spread radioactive material across 7,000 square miles in Europe.

The Chernobyl region remains uninhabited by humans. Shockingly, this has allowed a thriving wildlife ecosystem to reclaim the area, despite the dangerous radiation levels.

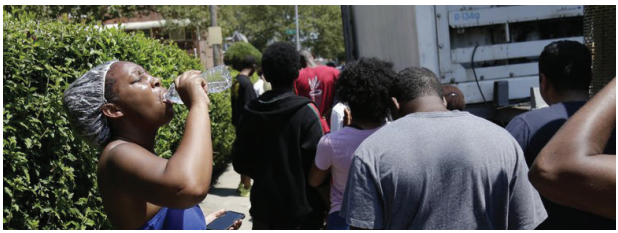
Energy & Technology

Blackout

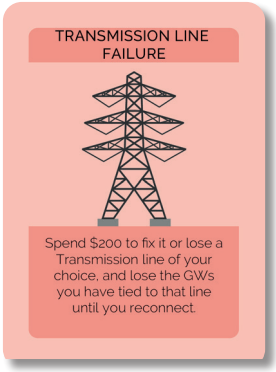
Heat waves leading to excess demand for electricity for air conditioning are a common and worsening cause of grid failure. “Our grid is going to be taxed in ways I don’t think we are prepared for,” said Kurt Shickman, executive director of the Global Cool Cities Alliance. During a 2019 heat wave, Con Edison intentionally cut power to 33,000 Southeast Brooklyn residents so the rest of the grid could handle the spike in demand. This largely unprecedented move came without warning at the expense of poorer areas in Brooklyn which ranked highly on the city’s heat vulnerability metric.

Cloudy Days

On cloudy days, solar panels’ productivity can be reduced by 90%. Solar + Batteries builds six hours of storage to compensate for hourly fluctuations and evening, but this won’t last for longer periods of reduced sunlight. A Cloudy Days Event decreases your stability by 2 points for every full GW of Solar, which can cause blackouts. Productivity is also severely diminished in winter, as there are fewer hours of sunlight. Since one turn is one full year, the winter limitation is factored into how solar works across the year.

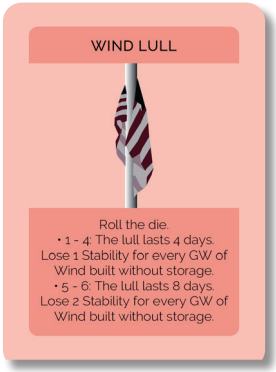


Right: Residents of Canarsie, Brooklyn, wait for dry ice after Con-Ed cut power during a heat wave. Canarsie ranks 4 out of 5 on NYC’s heat vulnerability index.



Transmission Line Failure

State investigators determined that the utility PG&E's downed transmission lines caused last fall's Camp Fire in California, the deadliest and most destructive wildfire in state history. This year, PG&E announced it would cut power for up to a week at a time when wildfire risk was high. Wind, storms and other extreme weather events destroy lines, and aging transmission lines can also fail. Most lines in the US transmission system are over 40 years old.



Wind Lull

Days without wind are common, and can severely strain a Wind-dependent grid. Large amounts of stored energy or on-demand power sources are vital. As noted in the section on Hydrogen, a Royal Society report estimates a demand for energy storage in the UK that is 1000 times the UK's current pumped hydro storage capacity.

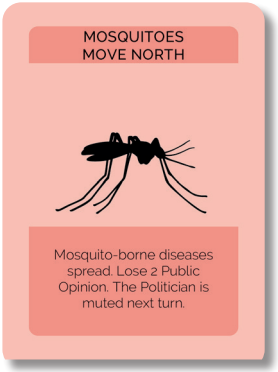
"Demand management" might also play a role in handling renewable intermittency by switching demand off and on to match supply. "Smart-charging" a fleet of EV batteries could help match demand with supply.

In the summer and fall of 2021, Europe experienced an extended lull, including in the UK more than a week without wind.

"Through summer and early autumn 2021, Europe experienced a long period of dry conditions and low wind speeds. The beautifully bright and still weather may have been a welcome reason to hold off reaching for our winter coats, but the lack of wind can be a serious issue when we consider where our electricity might be coming from."

What Europe's exceptionally low winds mean for the future energy grid, The Conversation, 10/21/2021

Public Health



Mosquitoes Move North

By 2050 disease-spreading mosquitoes will expand their range and may threaten 49% of the world's population, spreading malaria, dengue, and zika. By 2030, 100 million more people will be exposed to malaria due to climate change. By 2100, up to a billion additional people could be exposed to mosquito-borne diseases. Dengue, for example, may spread to places like Chicago and Copenhagen. In the US, the number of disease cases from mosquitoes, ticks, and fleas has tripled over the last 13 years.

Air Pollution

Globally, one out of six deaths is caused by air pollution. Some estimate that there will be 150 million more deaths due to air pollution alone at 2˚C of warming versus 1.5˚C. Droughts will cause more cases of "dust pneumonia," and deaths from dust pollution are expected to double. By 2090, 2 billion people will be breathing air every day above the WHO "safe" level, with massive adverse effects on health.

After E-Z Pass was introduced, premature births and low birth weight of babies in the vicinity of toll plazas reduced by 10.8% and 11.8%, respectively, just by cutting down the exhaust of cars slowing down to pay the toll.

Right: Mosquito netting. In 2016, yellow fever-carrying mosquitoes first left the Amazon basin.

Migrant Crisis

The IPCC predicts the "carrying capacity" of large parts of the world to be compromised by climate change. An unstable climate leads to newly uninhabitable areas, food and water shortages, insecurity, and violence. The UN forecasts 200 million environmental migrants by 2050. In 2011, 1 million climate refugees from Syria led to a European crisis. By 2100, sea-level rise alone could displace 13 million Americans.

As of November 2023, there are 100,000 migrant asylum seekers temporarily housed in New York City, including in large tents on Randall's Island.

Food Shock

Crop failures and food shocks due to changes in climate regimes will be one of the most devastating effects of the climate crisis. Extreme droughts much worse than the Dust Bowl are expected in breadbasket regions. Even where warming will unlock new farmland, like parts of Canada and Russia, it can take centuries to produce fertile soil. Excess CO_2 in the air also makes plants less nutritious: since 1995, protein, calcium, iron, Vitamin C, and more have all declined in the crops we grow.

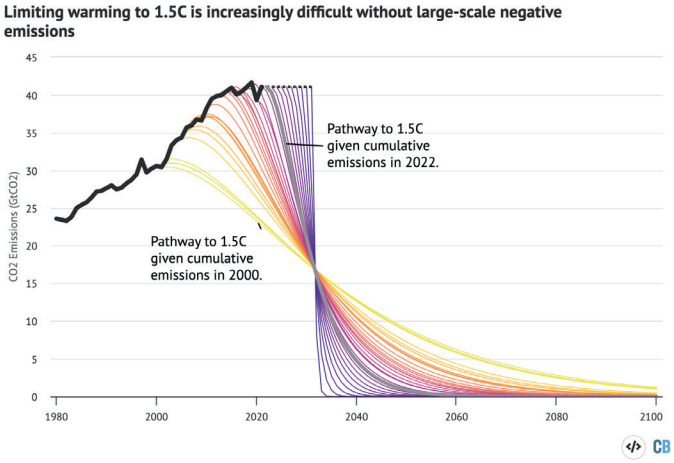
More CO_2 in the atmosphere hurts key plants and crops more than it helps, Yale Climate Connections, 12/13/2020

Left: Ravaged by drought, Hondurans can pray for rain or migrate.

Right: Farms sit underwater during the Midwest's 2019 growing season.

City Atlas

City Atlas is a public-facing project about the future of New York City, founded in 2011. City Atlas is built and operated by Artist As Citizen, Inc., a 501(c)3 corporation, under the guidance of the Institute for Sustainable Cities at Hunter College. The mission of City Atlas is to help New Yorkers understand and prepare for the future of the city, as described in the reports of New York City Panel on Climate Change (NPCC), the IPCC, and C40.org, and to strengthen the democratic process towards equitable responses to climate change.



Above: Emissions pathway according to Paris Climate Agreement, Carbon Brief

"States, cities, tribes, and communities will benefit from improved **energy literacy** among residents and leaders as they face increasingly consequential choices..."

National Academy of Sciences, "Accelerating Decarbonization in the United States: Technology, Policy, and Societal Dimensions" (2023)

Credit

The development of Energetic is a group effort by City Atlas teams of 2018/2019, and built upon work by prior years of City Atlas researchers. Energetic is a co-production of Artist As Citizen, Inc., a 501(c)3 corporation.

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This guide was produced in July 2019 and updated in November 2023. For more current references see links below.

Video tutorial and other resources:
newyork.thecityatlas.org/energetic/links/

Articles and press:
newyork.thecityatlas.org/energetic

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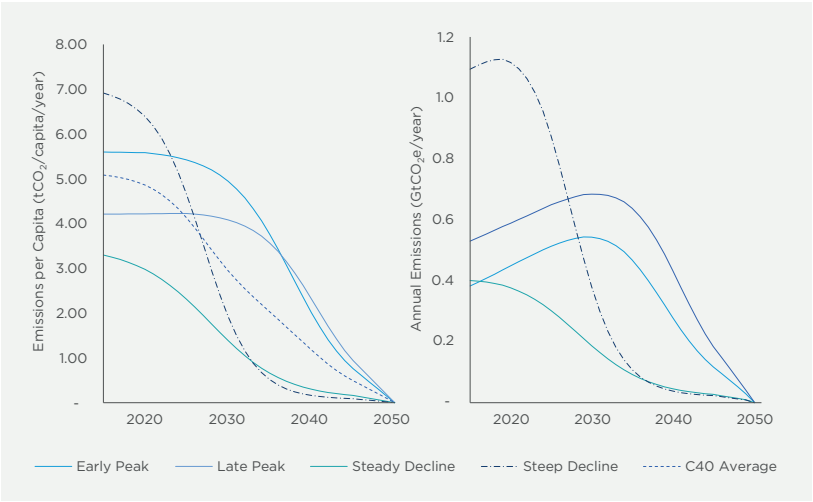
GHG/Capita	GDP/capita	Assigned typology	Example cities
High	High	*Steep Decline*	*Toronto* *Melbourne* *New York City*
	Low	*Early Peak*	*Cape Town* *Durban**
Low	High	*Steady Decline*	*Stockholm* *Seoul** *London*
	Low	*Late Peak*	*Quito* *Caracas** *Amman*

Figure 8. Projected average emissions per capita (left) and total annual emissions (right) for the four typologies under the 1.5 degree scenario.



Above: Emission pathways for 1.5 warming outlined by C40
https://www.c40.org/wp-content/uploads/2021/07/Deadline_2020.pdf