UNIVERSITÀ DI PAVIA
Dipartimento di Fisica
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Sezione di Pavia

Poweri noi! Watt should we do?

Educational Team Boardgame on Energy Transition and Renewable Energy

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Realized by PHYSICS for TEENAGERS

smr 4206 - Trieste - 23 June 2025

Framework

Education on sustainable development

to be introduced in school programmes

UNESCO - Agenda 2030
Otto et al. (2020)
Levrini et al. (2021)

Gamification e Game-based Learning

Motivation, participation and education

Law, S., & Jacobsen, M. (2015)
Roozenbeek & van der Linden, 2019
G. Mylonas et al. (2019)
Cook et al., 2022
Schubatzky & Haagen-Schützenhöfer (2023)

Scientific literature and fake-news debunking

Awareness on energetic and environmental choices

Bedford, 2016
Schubatzky, T., et al. (2022)
Kresin et al., 2024

Idea

Introduce the problems of the climate change and energy transition

Interactive and playful mode but suitable for in-class activity

Goal

Focus on the complexity of the energy situation of a Nation and on the pros and cons of each energy source, both from fossil fuels or renewable.

Players have to make strategic decision to prosper their nation in terms of health, education, and consensus of their citizen, being very careful about the emissions

Outline

Game rules

Gameplay

Debriefing

Educational strategies

Results

Game rules

Game rules

The winner is the nation who maximises their prosperity parameters health (), education (), and consensus (), increasing their energy () and keeping the lowest possible level of CO2 ().

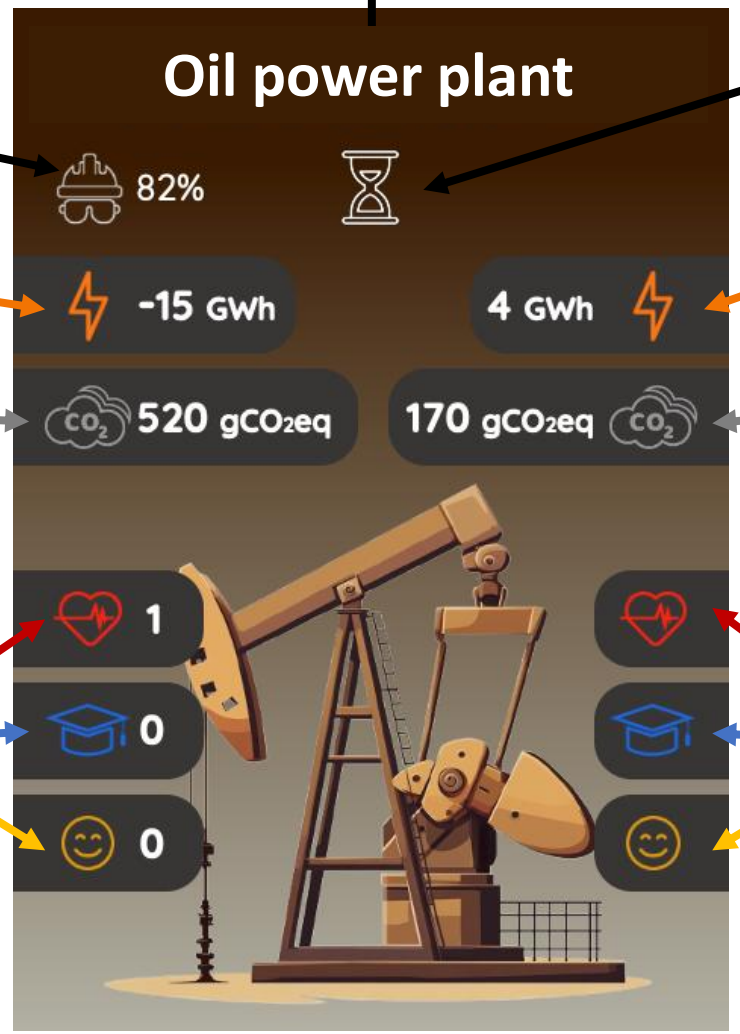
Game rules

The game is played using **different cards decks** (with graphic realized using AI tools)

Ideogram

Midjourney

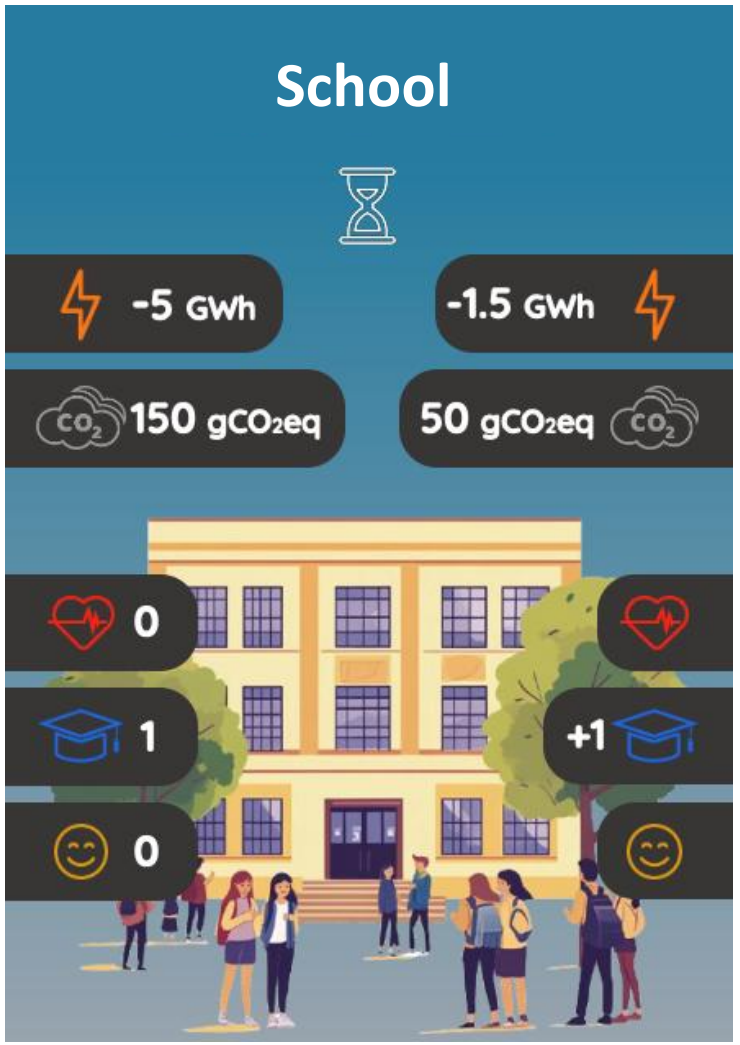
Game rules

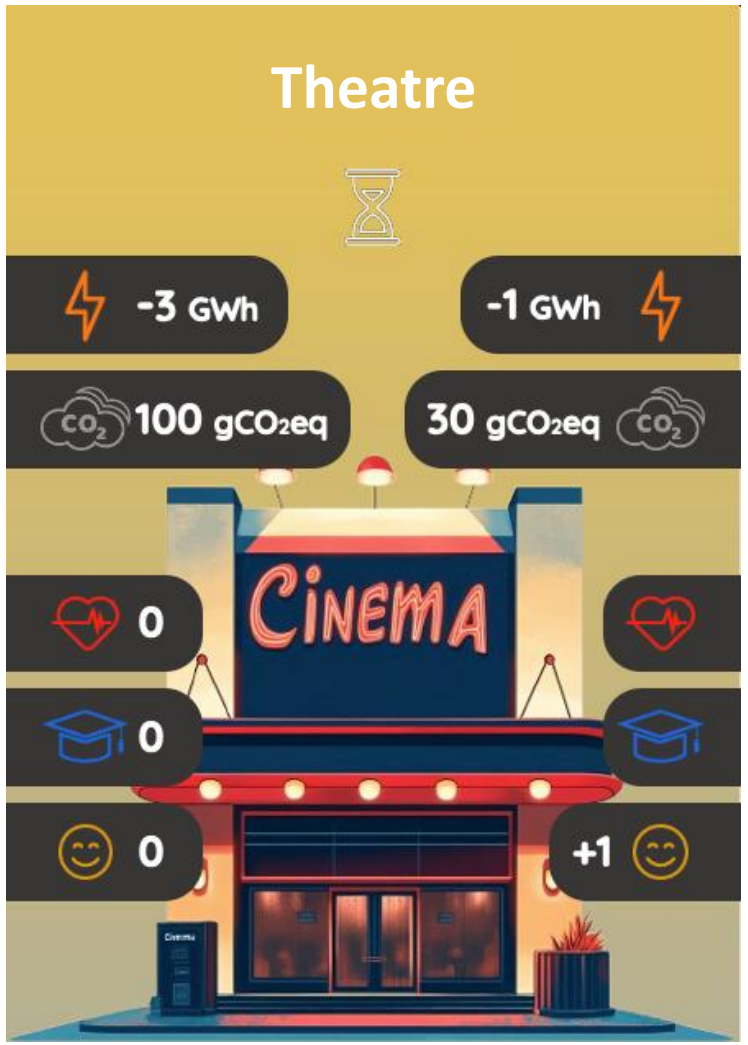


1. Name
2. Safety
3. Building time
4. Building cost
5. Maintenance energy
6. Building emission
7. Maintenance emission
8. Necessary prosperity parameters
9. Gained prosperity parameters

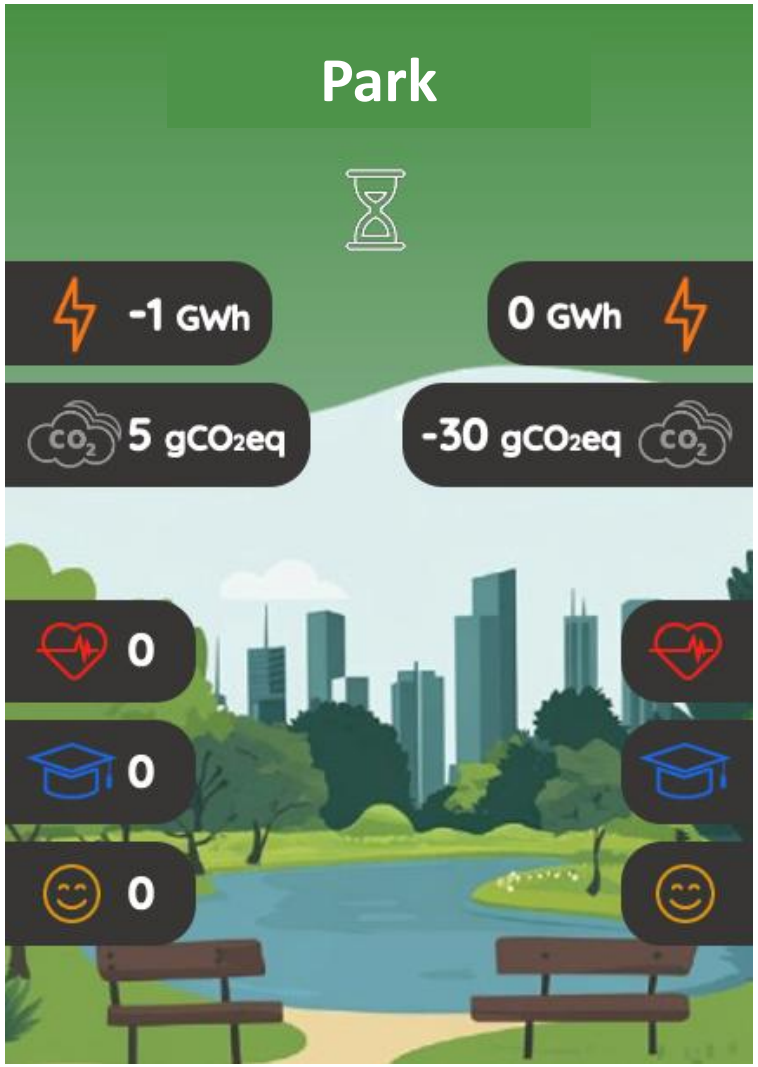
Game rules


Hospital
-7 GWh
-2 GWh
200 gCO2eq
70 gCO2eq
2
+1
0
0


School
-5 GWh
-1.5 GWh
150 gCO2eq
50 gCO2eq
0
1
0
+1


Theatre
-3 GWh
-1 GWh
100 gCO2eq
30 gCO2eq
CINEMA
0
0
0
+1

Game rules


Park
-1 GWh
0 GWh
5 gCO2eq
-30 gCO2eq
0
0
0


CNAO
-8 GWh
-3 GWh
250 gCO2eq
100 gCO2eq
3
+2
1
+1
1
NAO

Gameplay

@ Bergamo science festival

Maintenance phase

Investment phase

Draw phase

Activation/deactivation phase

Event phase

Gameplay

Turno 5

	Salute	Istruzione	Consenso	Energia (GWh)	CO2 (gCO2eq)	In costruzione	Produzione	Consumo
Carbonia	1.0 ❤️	1.0 🎓	1.0 😊	30.0 ⚡	1850.0 ☁️		5.0 ⚡	-4.0 ⚡
Petrolia	1.0 ❤️	1.0 🎓	-	25.0 ⚡	1850.0 ☁️		5.0 ⚡	-4.0 ⚡
Solaria	1.0 ❤️	-	-	12.0 ⚡	2070.0 ☁️	●	5.0 ⚡	-18.0 ⚡
Eolia	-	2.0 🎓	1.0 😊	25.0 ⚡	1850.0 ☁️		5.0 ⚡	-4.0 ⚡

Turno 6

	Salute	Istruzione	Consenso	Energia (GWh)	CO2 (gCO2eq)	In costruzione	Produzione	Consumo
Carbonia	-	1.0 🎓	1.0 😊	15.8 ⚡	2270.0 ☁️		5.0 ⚡	-19.0 ⚡
Petrolia	-	1.0 🎓	-	20.0 ⚡	2145.0 ☁️		5.0 ⚡	-5.0 ⚡
Solaria	-	1.0 🎓	-	11.0 ⚡	2680.0 ☁️		5.0 ⚡	-4.0 ⚡
Eolia	-	3.0 🎓	1.0 😊	16.0 ⚡	2420.0 ☁️		5.0 ⚡	-7.0 ⚡

Gameplay

Events

The Paris Agreement

In any round, if CO2 emission are > 300 gCO2eq pay a fee of 3 GWh

Gameplay

Events

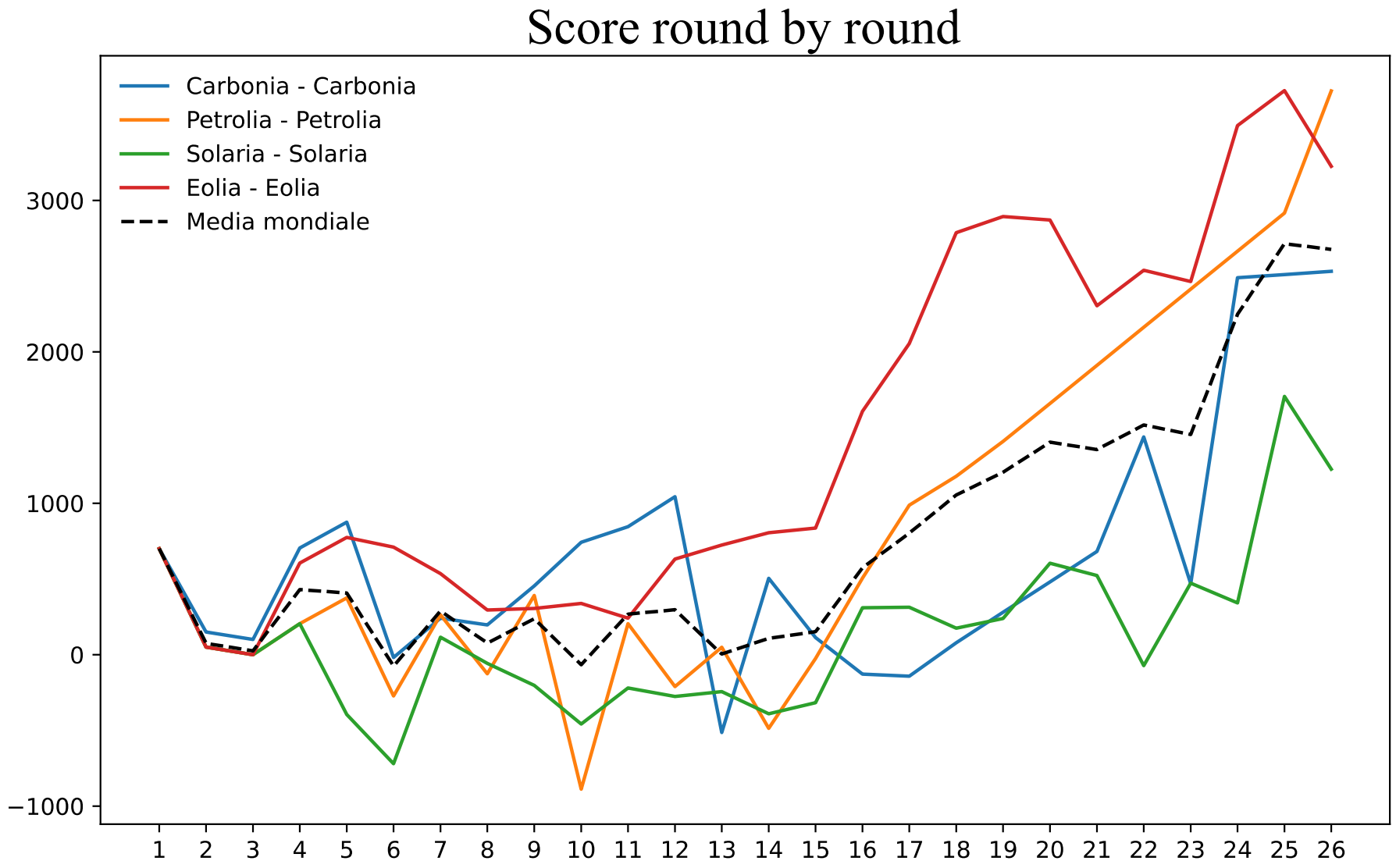
Climate change

If global CO2 emission are > 20000 gCO2eq any nation loses 1 point in health and one in consensus

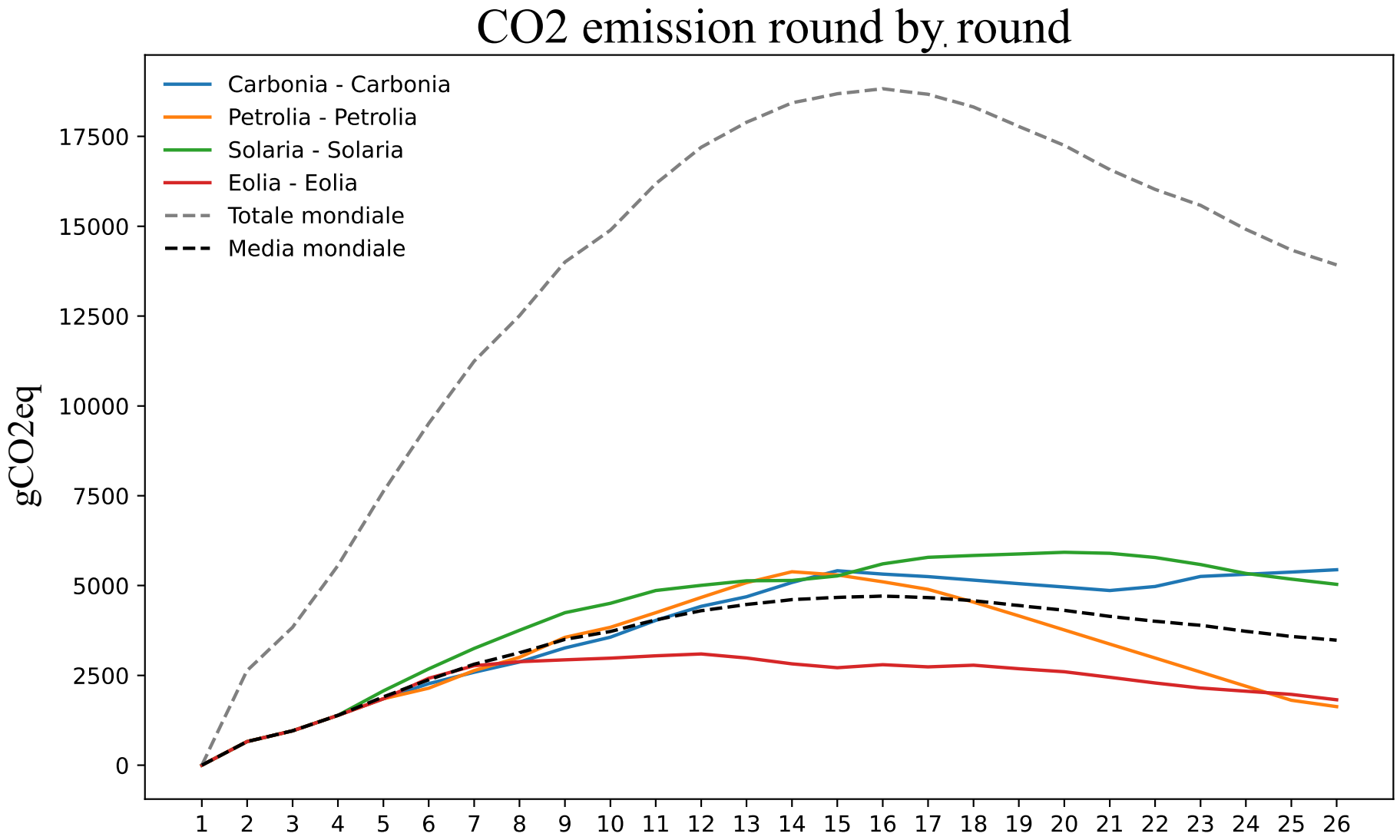
Debriefing

25 rounds
(about 2 hours
of play)

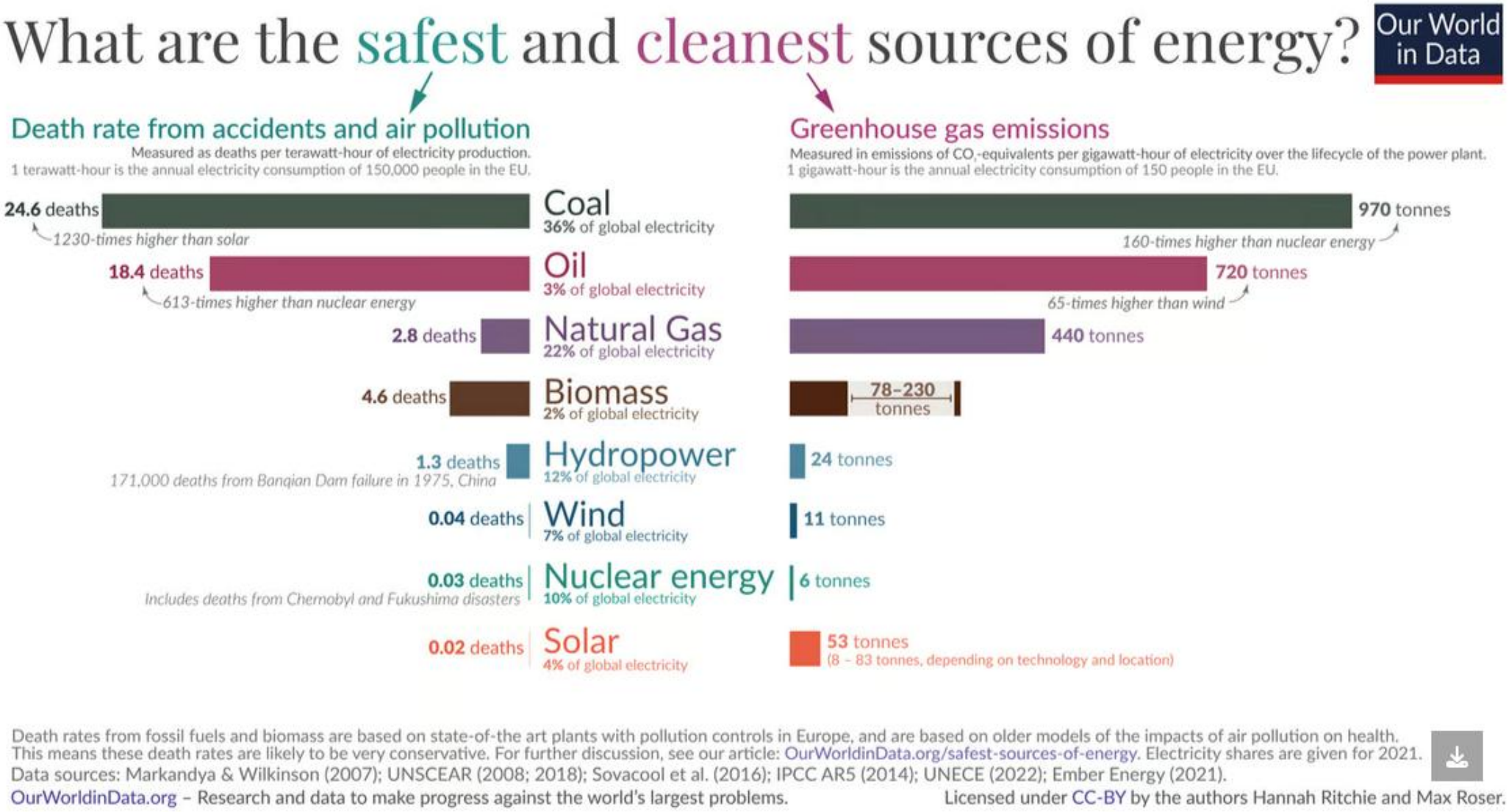
Plots realised
with a custom
python software



Debriefing

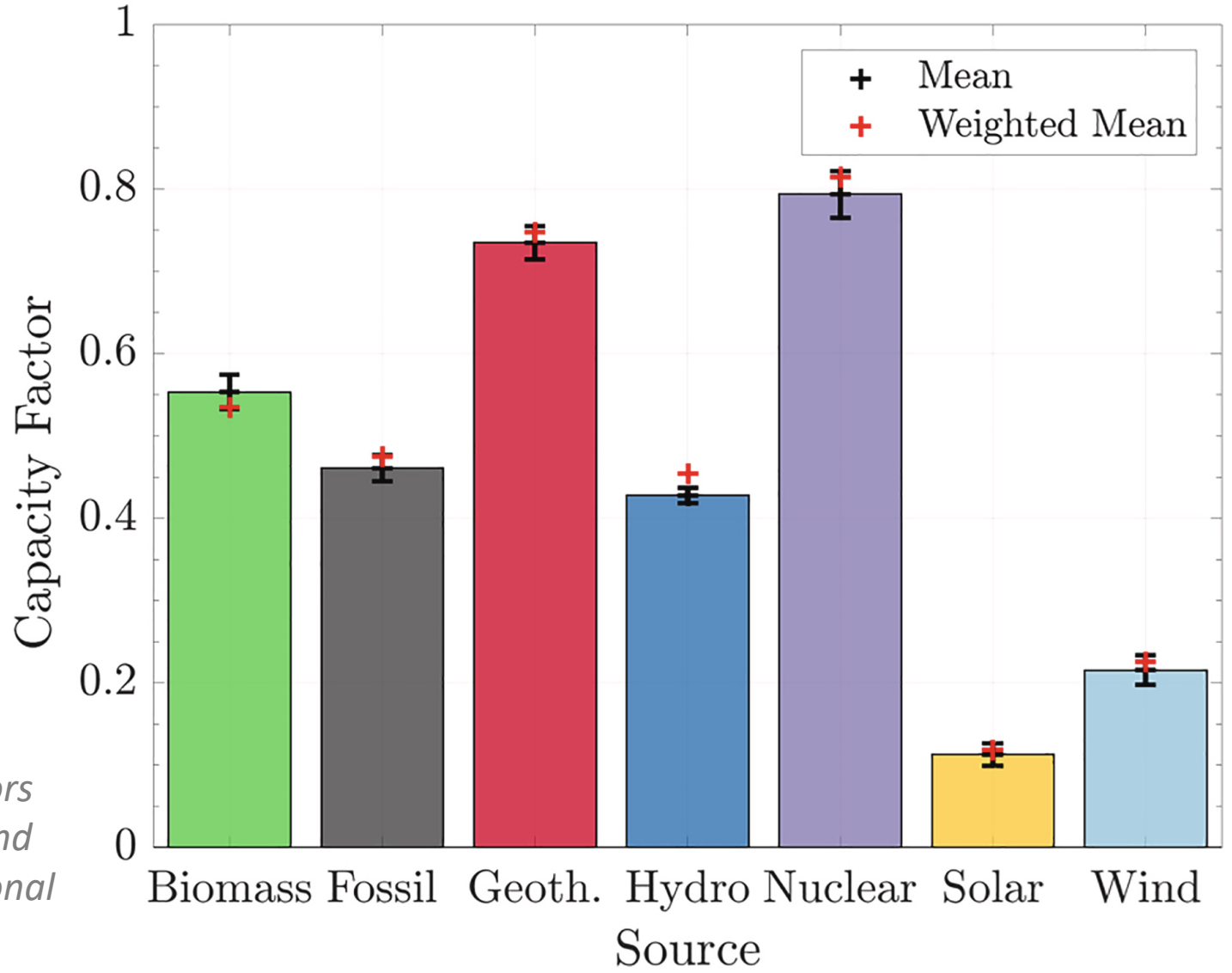

CO2 emission round by round
Carbonia - Carbonia
Petrolia - Petrolia
Solaria - Solaria
Eolia - Eolia
Totale mondiale
Media mondiale
gCO2eq
0
2500
5000
7500
10000
12500
15000
17500
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26

Debriefing


What are the safest and cleanest sources of energy?
Our World in Data
Death rate from accidents and air pollution
Measured as deaths per terawatt-hour of electricity production.
1 terawatt-hour is the annual electricity consumption of 150,000 people in the EU.
Greenhouse gas emissions
Measured in emissions of CO₂-equivalents per gigawatt-hour of electricity over the lifecycle of the power plant.
1 gigawatt-hour is the annual electricity consumption of 150 people in the EU.
24.6 deaths
1230-times higher than solar
Coal
36% of global electricity
970 tonnes
160-times higher than nuclear energy
18.4 deaths
613-times higher than nuclear energy
Oil
3% of global electricity
720 tonnes
65-times higher than wind
2.8 deaths
Natural Gas
22% of global electricity
440 tonnes
4.6 deaths
Biomass
2% of global electricity
78–230 tonnes
1.3 deaths
171,000 deaths from Banqiao Dam failure in 1975, China
Hydropower
12% of global electricity
24 tonnes
0.04 deaths
Wind
7% of global electricity
11 tonnes
0.03 deaths
Includes deaths from Chernobyl and Fukushima disasters
Nuclear energy
10% of global electricity
6 tonnes
0.02 deaths
Solar
4% of global electricity
53 tonnes
(8 – 83 tonnes, depending on technology and location)
Death rates from fossil fuels and biomass are based on state-of-the art plants with pollution controls in Europe, and are based on older models of the impacts of air pollution on health.
This means these death rates are likely to be very conservative. For further discussion, see our article: OurWorldinData.org/safest-sources-of-energy. Electricity shares are given for 2021.
Data sources: Markandya & Wilkinson (2007); UNSCEAR (2008; 2018); Sovacool et al. (2016); IPCC AR5 (2014); UNECE (2022); Ember Energy (2021).
OurWorldinData.org – Research and data to make progress against the world's largest problems.
Licensed under CC-BY by the authors Hannah Ritchie and Max Roser.

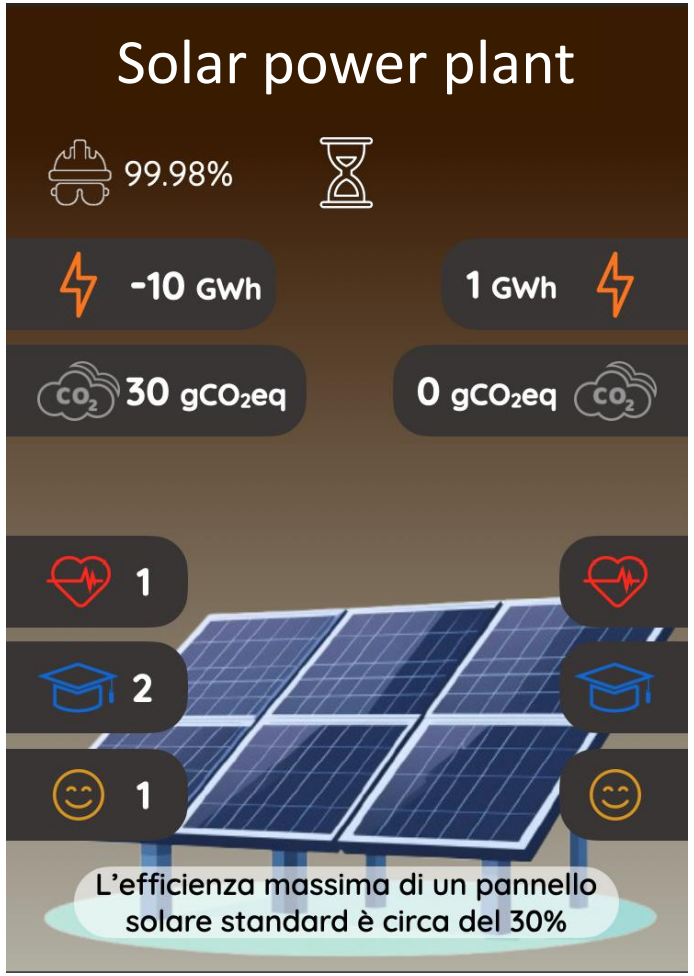
Debriefing

Capacity factor for energy production values in the different cards

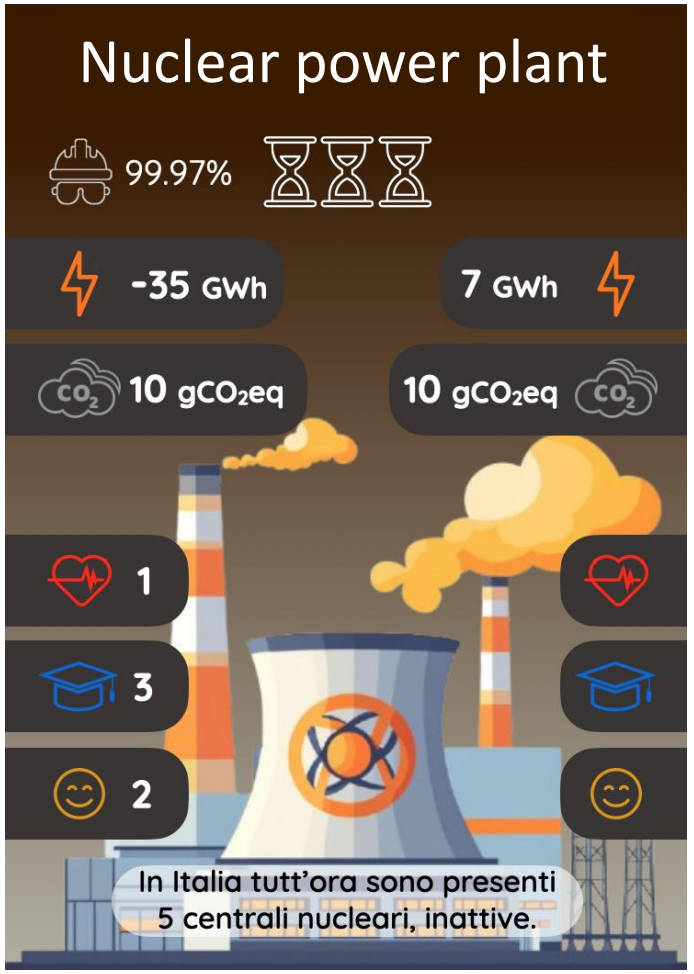


[Bolson, N., Prieto, P., & Patzek, T., "*Capacity factors for electrical power generation from renewable and non-renewable sources*", *Proceedings of the National Academy of Sciences (2022)*]

Educational strategies: from cards



Low production, low cost

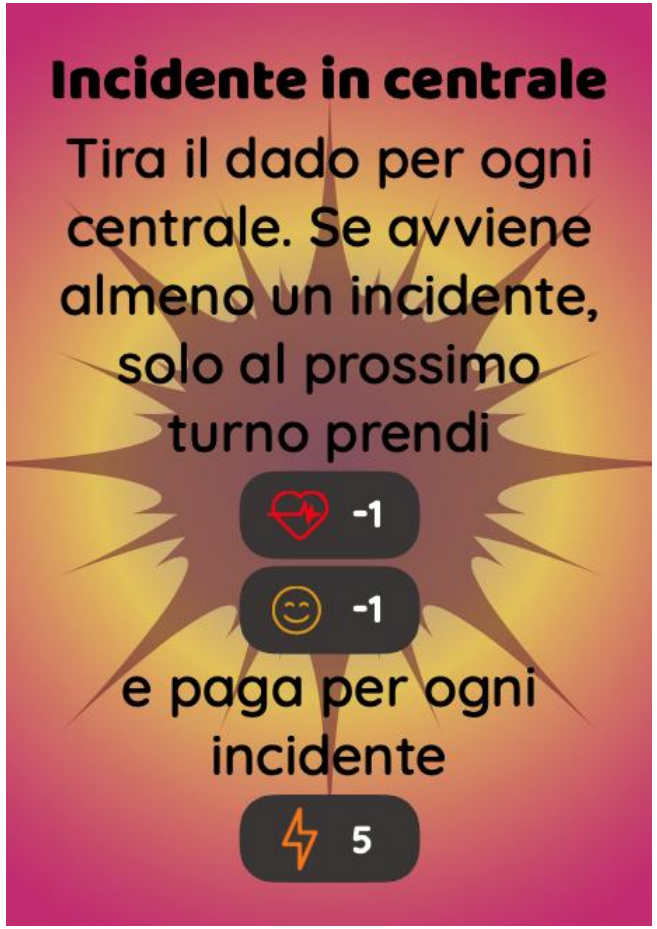


High production, high cost, low emission, low risk

High production, high cost

Educational strategies: from events

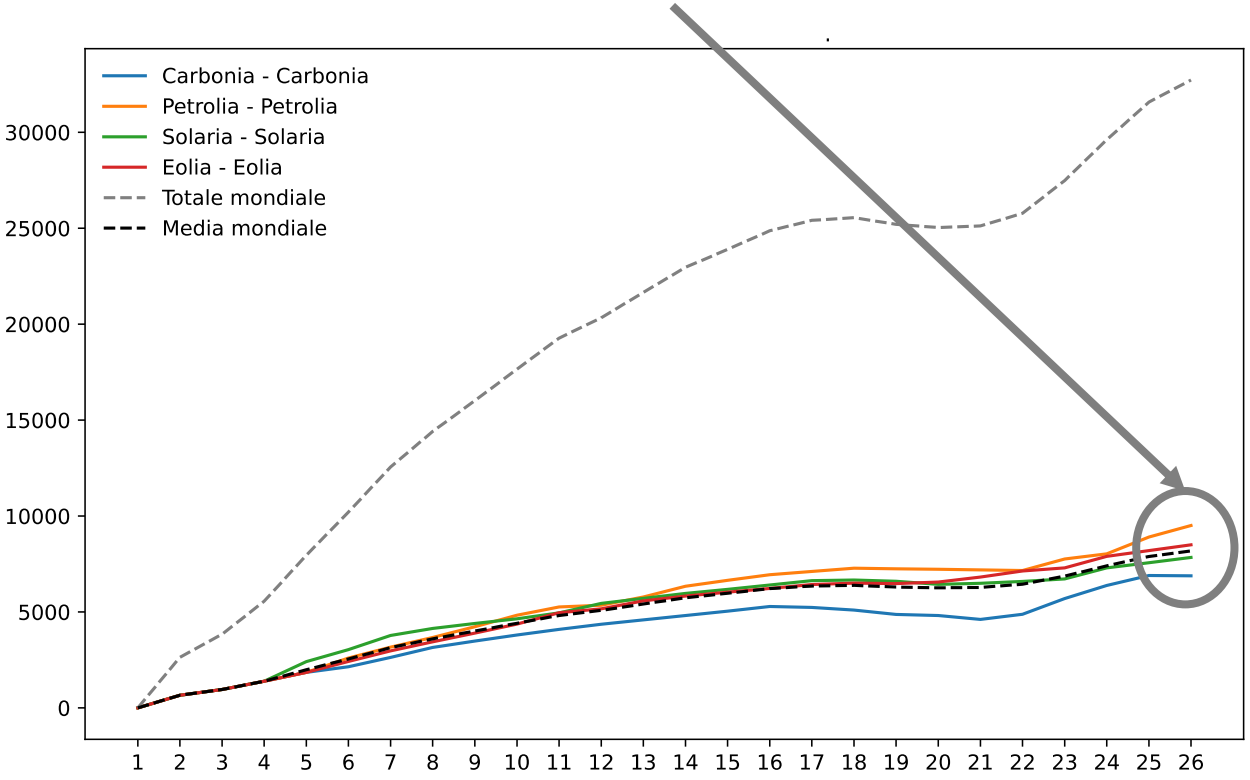
Disaster at the power plant



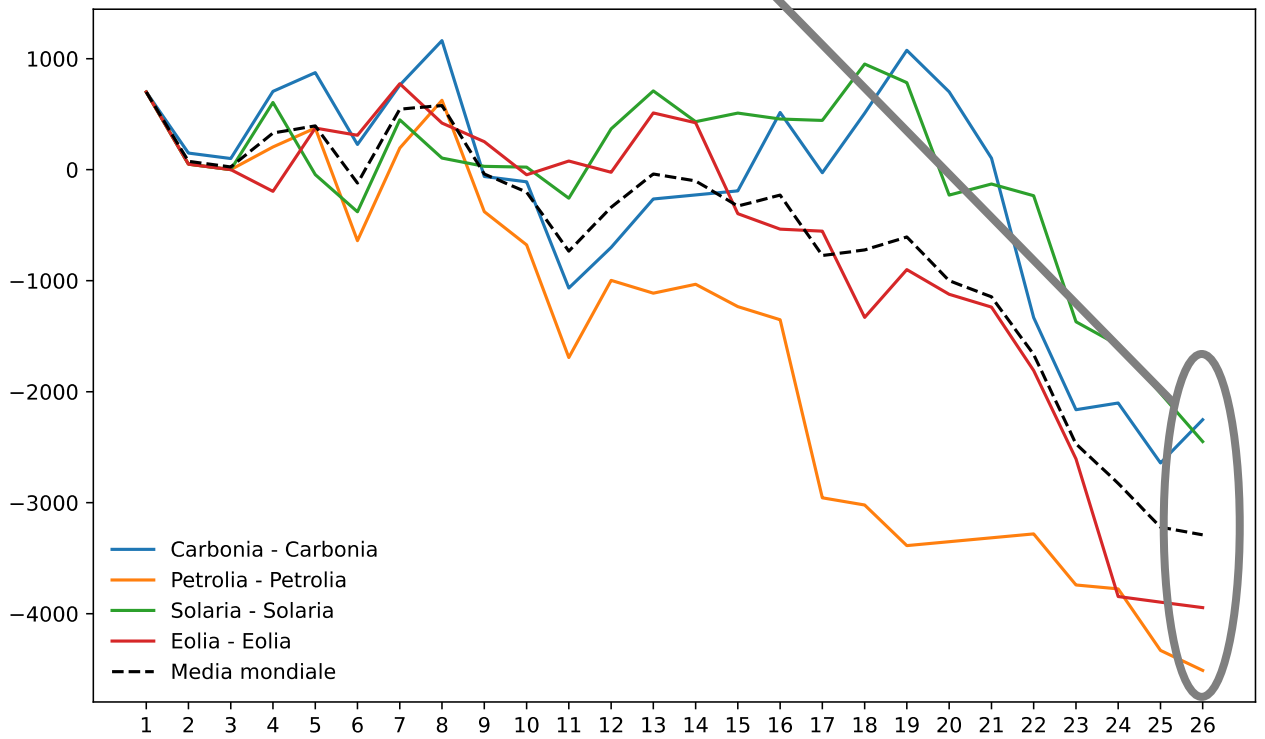
Power	Probability	if «1» throwing
	$P = \frac{25}{100}$	D4
	$P = \frac{5}{100}$	D20
	$P = \frac{1}{100}$	D10 D10
	$P = \frac{0.03}{100}$	D4 D10 D10
	$P = \frac{0.02}{100}$	D12 D12 D20

Educational strategies: from the game

High emission



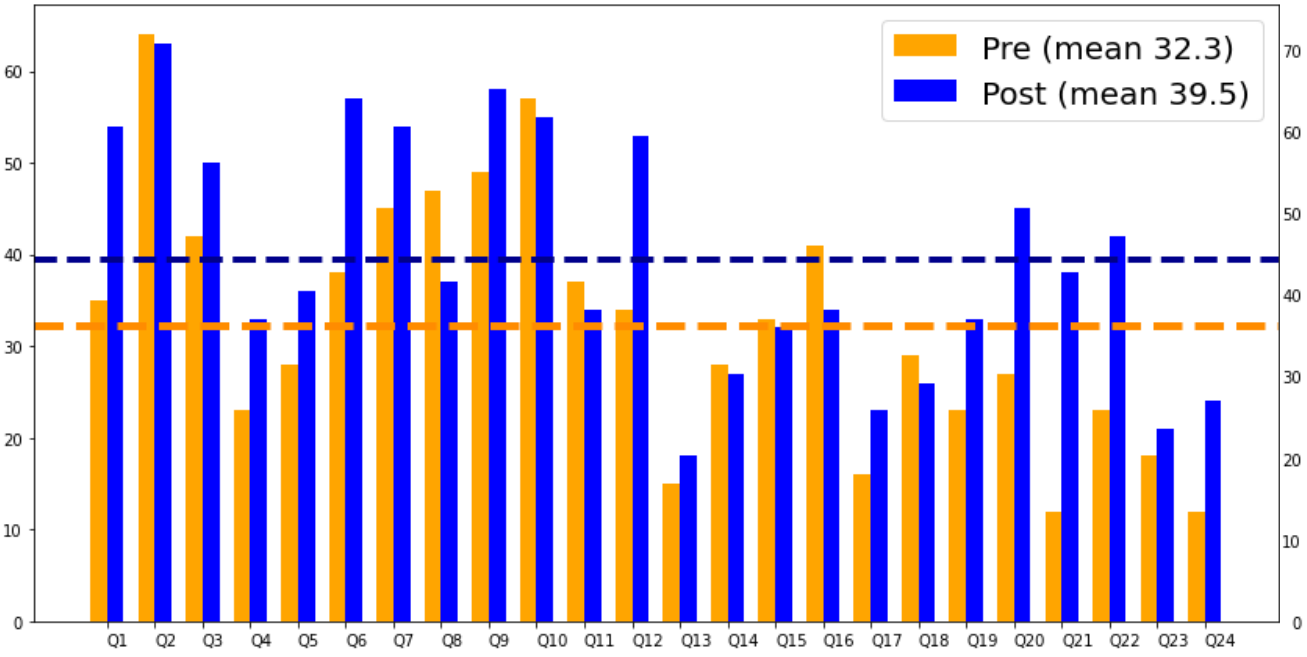
Negative score



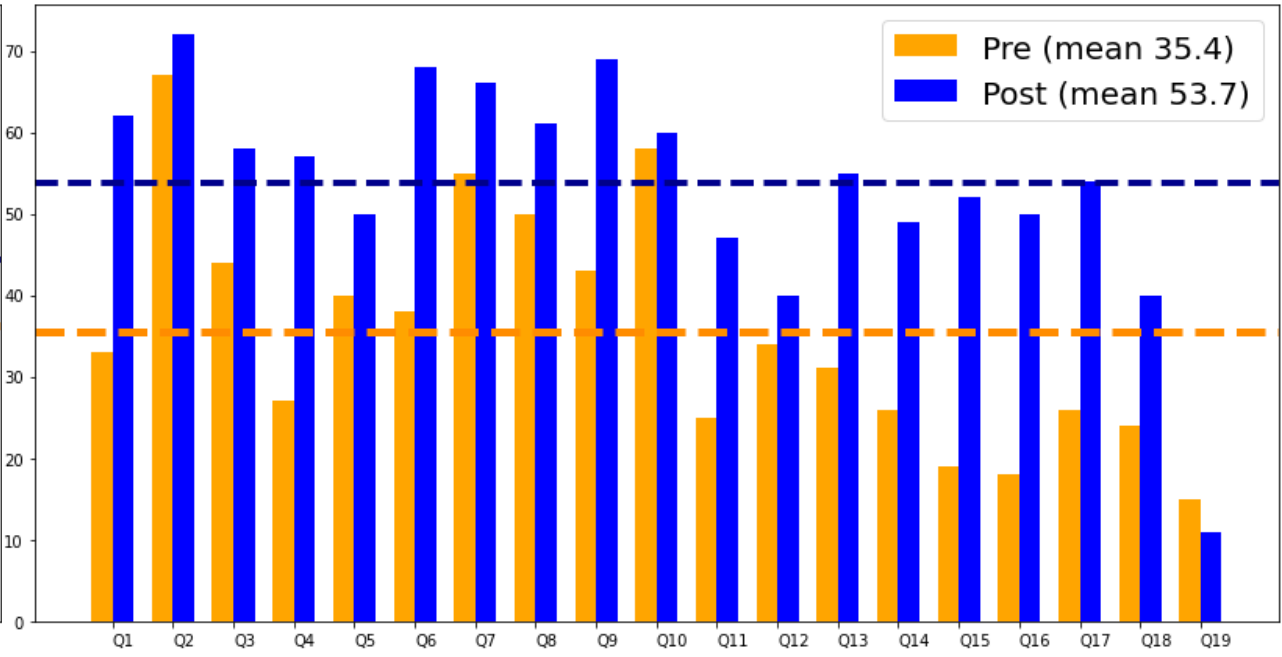
Results: pre-post didactic questionnaire

Multiple choice questionnaire (5 answers, 1 correct)

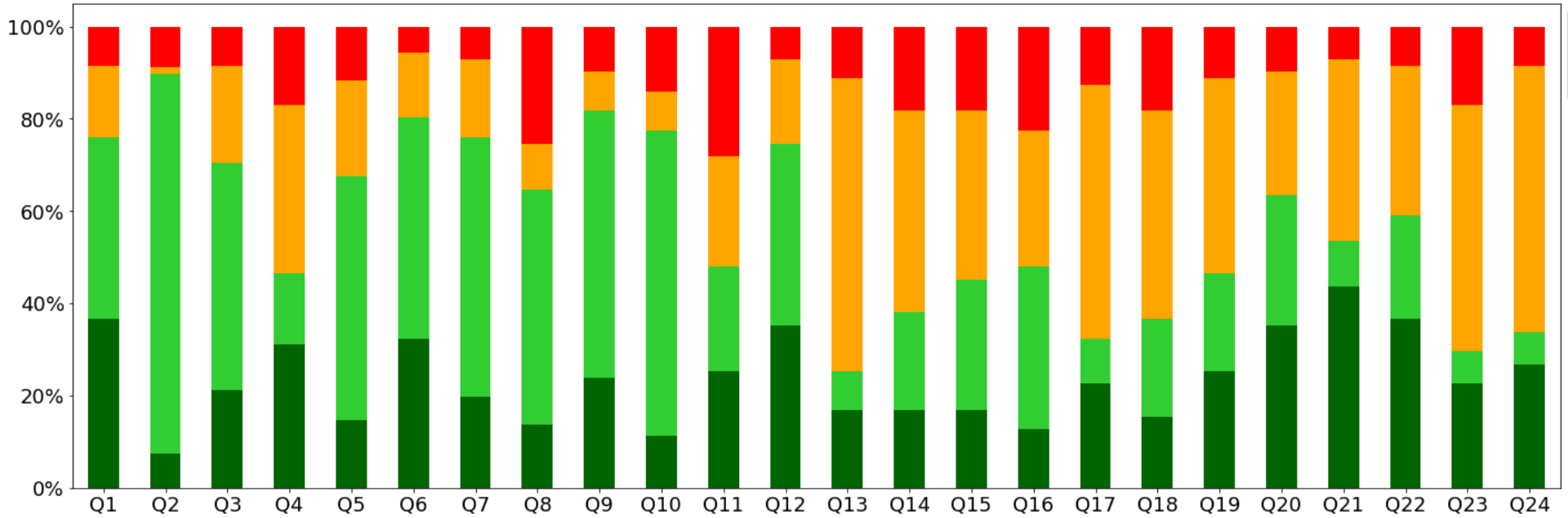
Number of correct answers (72 students)



Number of correct answers (73 students)



Results: pre-post didactic questionnaire



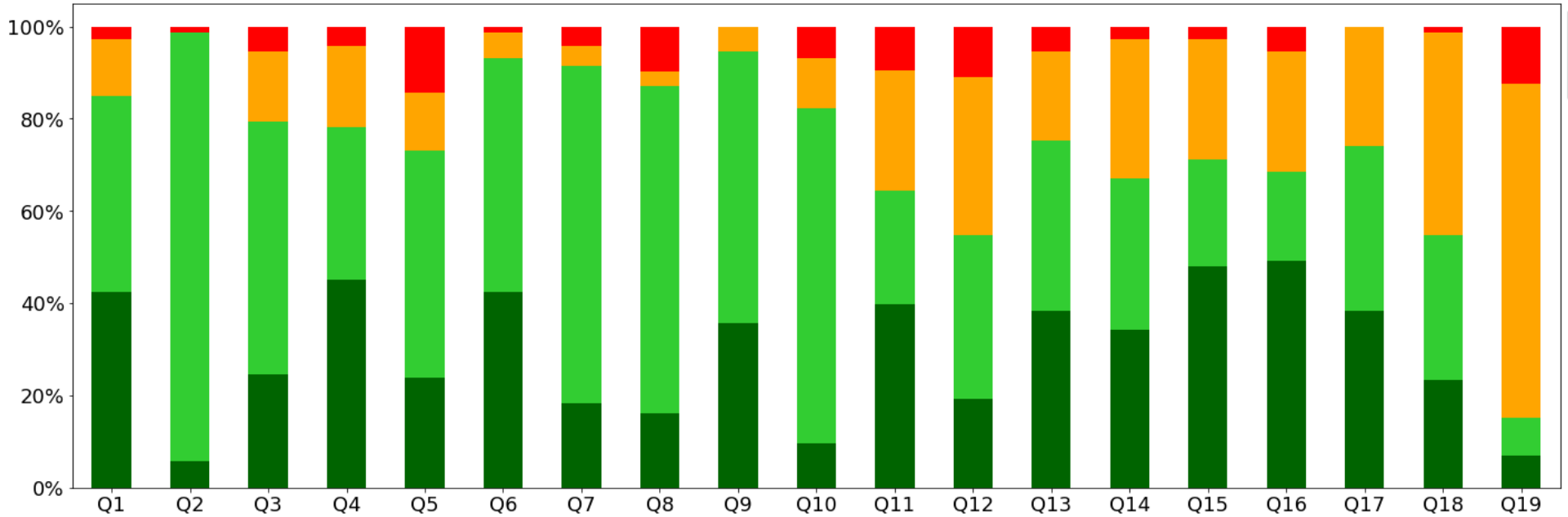
Pre - Post

Wrong → Correct

Correct → Correct

Wrong → Wrong

Correct → Wrong



Results: pre-post didactic questionnaire

Q15 contingency

Which is the most used renewable source in Italy?

	Post Correct	Post Wrong 1	Post Wrong 2	Post Wrong 3	Post Wrong 4
Pre Correct	23.3%	0.0%	1.4%	0.0%	1.4%
Pre Wrong 1	19.2%	8.2%	1.4%	1.4%	0.0%
Pre Wrong 2	8.2%	1.4%	1.4%	0.0%	1.4%
Pre Wrong 3	2.7%	2.7%	0.0%	1.4%	0.0%
Pre Wrong 4	17.8%	2.7%	0.0%	1.4%	2.7%

C: Hydroelectric
W1: Wind
W2: Geothermic
W3: I don't know
W4: Solar

Students that answered "Solar":
Pre: 21.9% → Post: 4.1%

Results: pre-post didactic questionnaire

Q16 contingency

How many nuclear power plants are present in Italy?

	Post Correct	Post Wrong 1	Post Wrong 2	Post Wrong 3	Post Wrong 4
Pre Correct	19.2%	0.0%	1.4%	4.1%	0.0%
Pre Wrong 1	1.4%	2.7%	0.0%	0.0%	1.4%
Pre Wrong 2	1.4%	0.0%	0.0%	1.4%	0.0%
Pre Wrong 3	39.7%	0.0%	0.0%	17.8%	0.0%
Pre Wrong 4	6.8%	0.0%	0.0%	0.0%	2.7%

C: 5
W1: 1
W2: 10
W3: None
W4: I don't know

Students that answered "None":
Pre: 57.5% → Post: 21.9%

Results: pre-post didactic questionnaire

Q19 contingency

Which countries are more exposed to climate change?

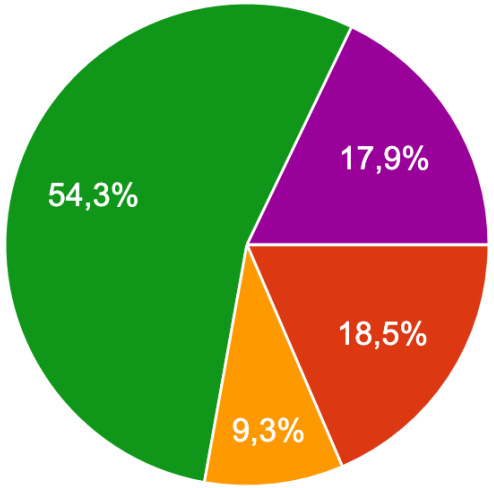
	Post Correct	Post Wrong 1	Post Wrong 2	Post Wrong 3	Post Wrong 4
Pre Correct	8.2%	0.0%	2.7%	0.0%	9.6%
Pre Wrong 1	0.0%	6.8%	0.0%	0.0%	12.3%
Pre Wrong 2	2.7%	0.0%	4.1%	0.0%	2.7%
Pre Wrong 3	0.0%	0.0%	0.0%	0.0%	8.2%
Pre Wrong 4	4.1%	1.4%	0.0%	0.0%	37.0%

C: Developing countries
W1: Countries facing the the sea
W2: Developed countries
W3: I don't know
W4: All countries in the same way

Students that answered
"All countries in the same way":
Pre: 42.5% → Post: 69.8%

Results: satisfaction questionnaire (151 answers)

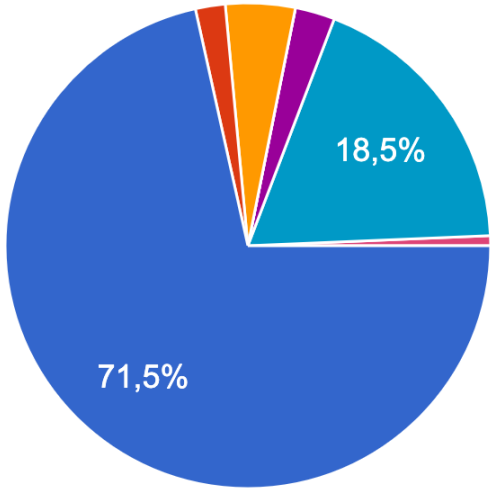
Which class do you attend?



- I grade
- II grade
- III grade
- IV grade
- V grade
- Other

In Italy high school lasts 5 years

What kind of school do you attend?

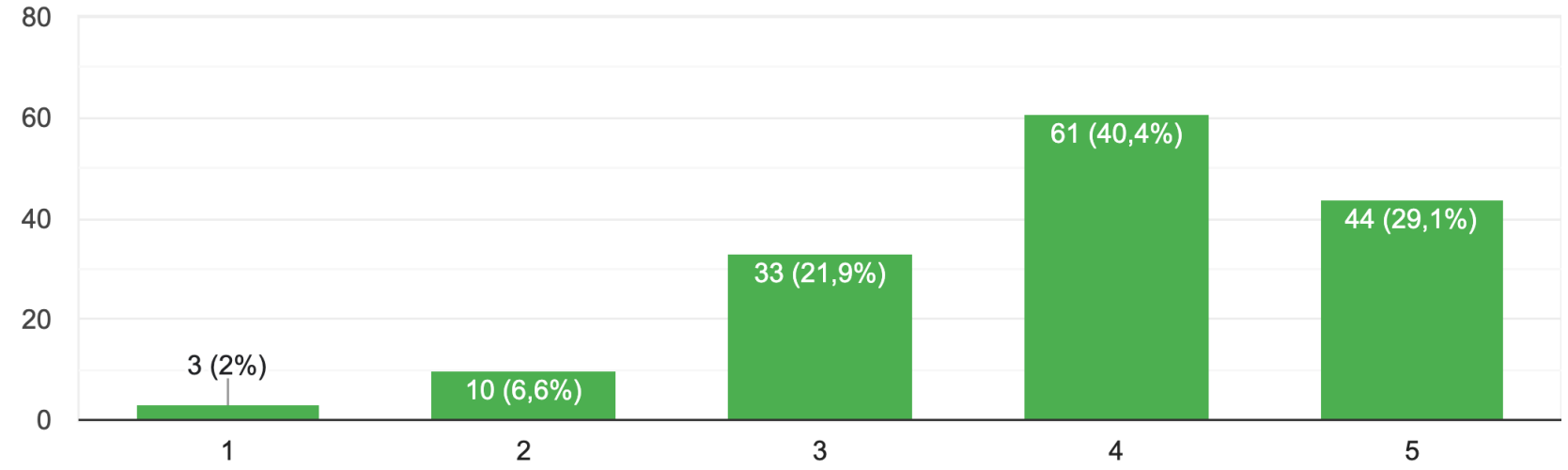


- Scientific high school
- Classic high school
- Human studies high school
- Artistic high school
- Technical institute
- Professional institute
- Other

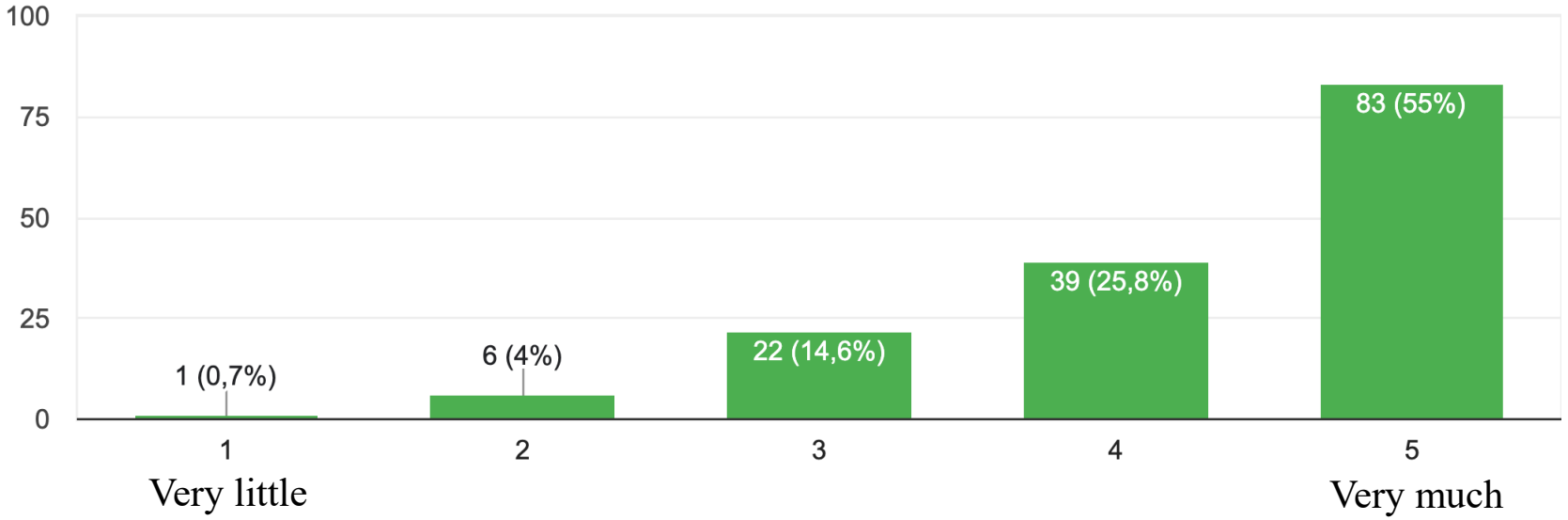
Results: satisfaction questionnaire (151 answers)

Satisfaction questionnaire (151 answers)

How much did the activity allow you to deepen your previous knowledge?



Does the format seem effective to you?



Conclusion

The game is an activity well suited for schools' lectures about climate and energy

Powered by PHYSICS for TEENAGERS

Game dynamics are quite simple, the big difficulty lies in calculating the scores, hence the need for a code that manages the game

Teaching effectiveness is certainly linked to the time dedicated to the activity. More sessions will provide more details about activity weaknesses

Thanks for the attention