Babeș-Bolyai University
Faculty of Mathematics and Computer Science

Curs opțional
Modele de inteligență artificială în schimbarea climatică

Sustenabilitate Computațională

Încălzirea globală

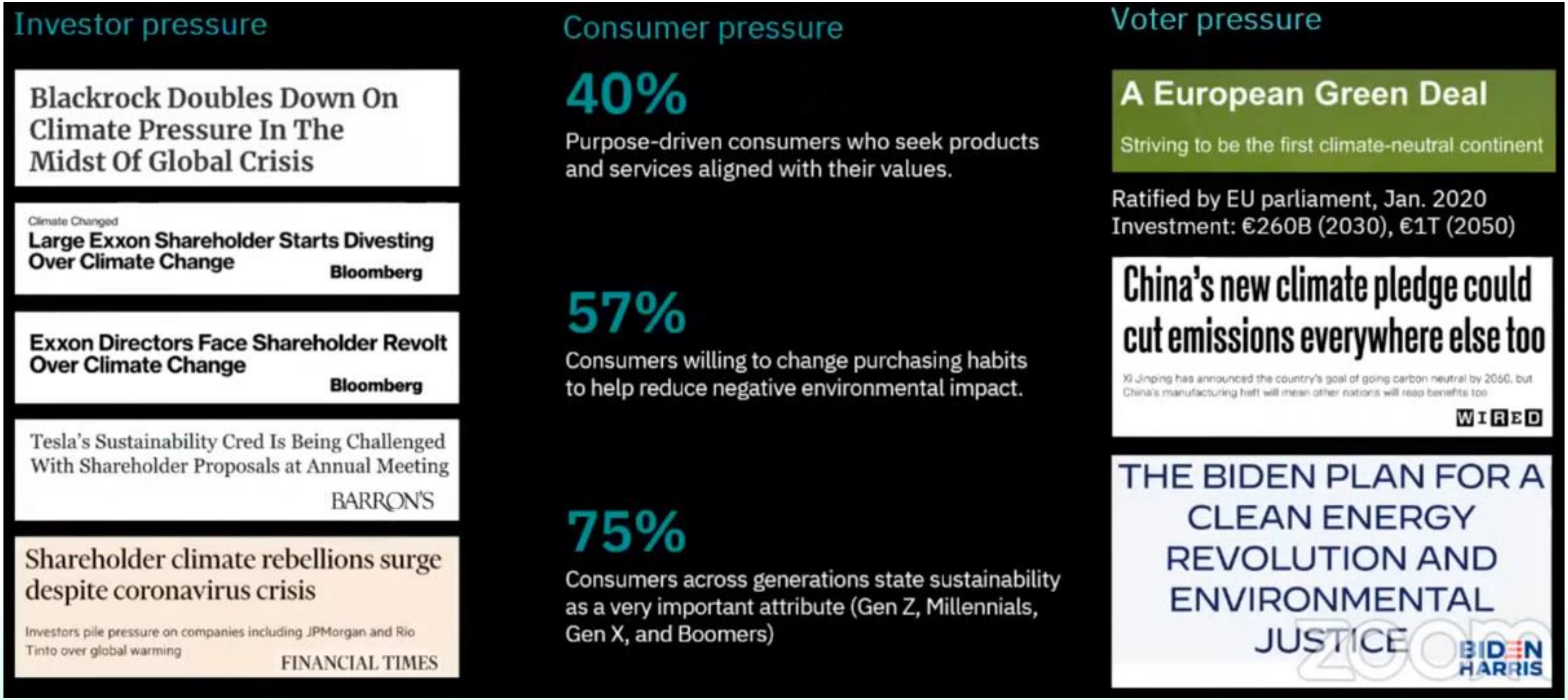
A provocat și va provoca un număr tot mai mare de evenimente climatice extreme:

- inundații
- secete
- precipitații extreme
- valuri de căldură
- incendii forestiere
- deficit de apă
- dispariția ghețarilor
- creșterea nivelului mărilor
- modificarea distribuirii sau chiar dispariția unei părți a faunei și a florei
- daune plantelor, legumelor si fructelor
- penurii de alimente și de apă dulce
- **=> migrația populațiilor care încearcă să scape de aceste pericole**

Riscurile de schimbări ireversibile și catastrofice vor crește semnificativ în cazul în care încălzirea globală va depăși cu 1,5°C [1]

Soluții?

Around the world ...



But first … definitions

SUSTENABILITÁTE, s.f. **1.** (Econ.) Caracteristică a unei activităţi de a putea fi desfăşurată pe o perioadă lungă de timp. **2.** (Ecol.) Utilizare şi dezvoltare a resurselor naturale fără a conduce la epuizarea acestora sau la degradarea mediului înconjurător. – Cf. engl. sustainability.

Definition of *sustainable*

1 **:** capable of being sustained

2 **a** **:** of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged

// *sustainable* techniques

// *sustainable* agriculture

b **:** of or relating to a lifestyle involving the use of sustainable methods

// *sustainable* society

Sustenabilitate computațională

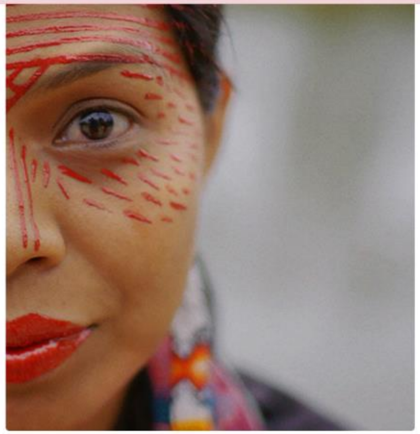
Computational sustainability is an interdisciplinary research field with the overall goal of developing **computational models, methods,** and **tools** to help manage the balance between environmental, economic, and societal needs for sustainable development [2].

A video presenting the concept **Computational sustainability** is here:
https://dl.acm.org/doi/abs/10.1145/3339399

[2] Gomes C.P. (2011) Computational Sustainability. In: Gama J., Bradley E., Hollmén J. (eds) Advances in Intelligent Data Analysis X. IDA 2011. Lecture Notes in Computer Science, vol 7014. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-24800-9_2

Google
https://sustainability.google/

https://sustainability.google/technology/



INDIGENOUS MAPPING

Explore an interactive experience that connects you to the rainforest using Google Earth.

Read story   Visit tool

accelerate the transmission to a low-carbon future.

Read story   Visit tool

EARTH ENGINE

Provides satellite imagery, geospatial

Our technology is empowering our partners to accelerate meaningful change.

All partner stories →

WITH EXPERTS

Meet the team using machine learning to help save the world's bees

Read story

Microsoft: AI for Earth
https://www.microsoft.com/en-us/ai/ai-for-earth-tech-resources

Areas of focus

AI for Earth awards grants to support projects that use AI to change the way people and organizations monitor, model, and manage Earth's natural systems. To date, we have awarded over 700 grants to projects with impact in over 80 countries, and we are committed to growing this community of grantees.

Climate

The changing climate threatens human health, infrastructure, and natural systems. AI can give people more accurate climate predictions to help reduce the potential impacts.

Agriculture

By 2050, farmers must produce more food, on less arable land, and with less environmental impact to feed the world's increasing population. AI can help people monitor the health of farms in real time.

Biodiversity

Species are going extinct at an alarming rate. AI can help accelerate the discovery, monitoring, and protection of biodiversity across our planet.

Water

In the next two decades, demand for fresh water is predicted to dramatically outpace supply. AI can help people model Earth's water supply to help us conserve and protect fresh water.

Amazon
https://sustainability.aboutamazon.com/

As part of Amazon's mission to be Earth's most customer-centric company, we are committed to building a sustainable business for our employees, customers, and communities. We are driving toward a net-zero carbon future where the people that support our entire value chain are treated with dignity and respect.

Net-Zero Carbon

Reaching net-zero carbon emissions across our operations by 2040

Renewable Energy

On a path to powering our operations with 100% renewable energy by 2025

Shipment Zero

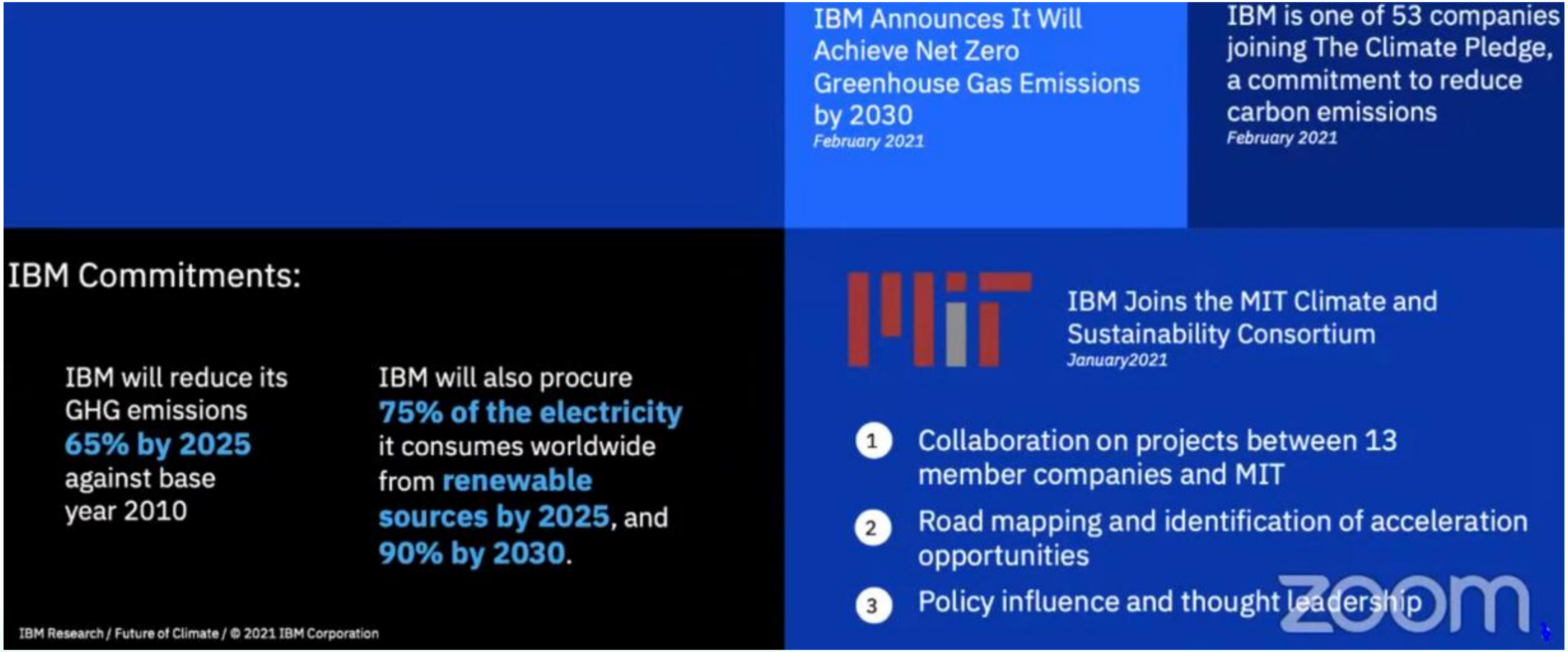
Making 50% of all shipments net-zero carbon by 2030

Electric Delivery Vehicles

Deploying 100,000 custom electric delivery vehicles by 2030

IBM

https://www.ibm.com/ibm/environment/climate/position.shtml



Costul acțiunii versus costul non-acțiunii [1]

”Conform raportului Stern [1], publicat în 2006, **lupta** împotriva încălzirii globale ar costa în jur de 1 % din PIB-ul mondial în fiecare an;

Lipsa de acțiune ar putea costa cel puțin 5 % și, în cel mai rău caz, până la 20 % din PIB-ul mondial.

Astfel, ar fi nevoie doar de o mică parte a PIB-ului mondial total pentru a investi într-o economie cu emisii scăzute de carbon, dar combaterea schimbărilor climatice ar genera, în schimb, beneficii la nivelul sănătății, o siguranță energetică sporită și ar reduce alte daune.”

Sursa informatiei:

[1] https://www.europarl.europa.eu/factsheets/ro/sheet/72/lupta-impotriva-schimbarilor-climatice

Adaptarea la schimbările climatice

Adaptarea la schimbările climatice variază:

măsuri ușor de realizat și necostisitoare

- raționalizarea apei
- rotația culturilor
- utilizarea de culturi rezistente la secetă
- planificarea publică și sensibilizarea populației

măsuri costisitoare de protecție și strămutare

- creșterea înălțimii digurilor
- relocalizarea porturilor, a industriei și a populației din zone de coastă joase sau din câmpii inundabile

Strategia UE privind adaptarea la schimbările climatice are drept scop construirea unei Europe mai rezistente la schimbările climatice.

Aceasta promovează un grad mai mare de coordonare și de schimb de informații între statele membre și favorizează integrarea adaptării în toate politicile relevante ale UE.

Care este situatia concreta?

UE are propuse proiecte de limitare a schimbarii globale si de combatere a incalzirii climatice.

Printre proiecte se numara:

Infrastructură pentru energie verde și accesibilă:

- democratizarea consumului energetic și susținerea prosumatorilor
- protejarea biodiversității
- conservarea și extinderea pădurilor.

Unele state le implemeneteaza, altele ...

Dar ce face concret?

https://app.sli.do/event/489UpohXUR9ZWpLLVM5Ppj/embed/polls/4af591de-9c5a-46e7-adc3-32671c31dfcf

https://www.youtube.com/watch?fbclid=IwAR3uePgz8R1CQpnCt2OTnqLGAdfmZbi8yTadIvOSxKTGmMtnQJKc-aJqwoc&v=VtS4AyjGV4I&feature=youtu.be

Ce ar trebui sa facă țara noastră? [sursa greenpeace]

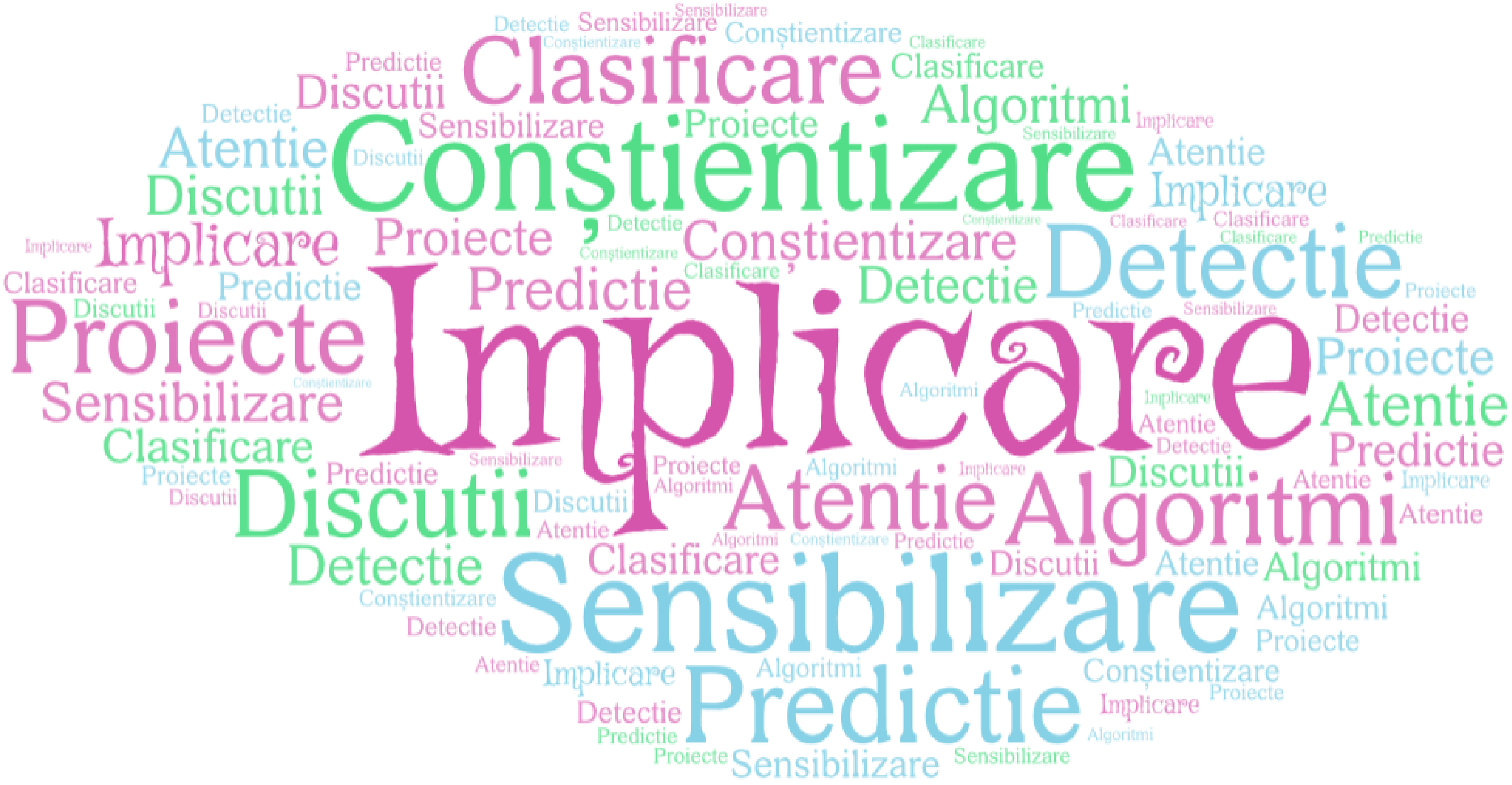
România trebuie să:

- prioritizeze crearea rețelelor de transport public bazate pe energie regenerabilă
- modernizeze infrastructura feroviară existentă
- îmbunătățească și să extindă rapid infrastructura pentru biciclete și pietoni
- încurajeze extinderea serviciilor de micro-mobilitate
- implementeze restricții rutiere precum zone cu emisii reduse sau zone închise traficului rutier
- legifereze accelerarea procesului de renunțare la mașinile diesel și pe benzină
- susțină construcția stațiilor de încărcare pentru vehicule electrice

Efecte ale schimbărilor climatice in tara noastra sunt deja vizibile:

- ➢ deșertificarea din sud continuă în ritm accelerat
- ➢ secetă fără precedent în zonele de campe
- ➢ inundații puternice

... from idea to action!



Obiectiv și obiective ... la nivel ... nano

Identificarea soluțiilor utile pentru limitarea schimbării climatice folosind tehncii și metode ale Inteligenței Artificiale

- **Identificarea** unora dintre problemele **actuale** și **rezolvabile** care țin de Schimbarea Climatica;
- **Modelarea** acestor probleme;
- **Propunerea** de soluții sub forma unor **proiecte/aplicații** care să fie văzute ca și posibile răspunsuri la probleme identificate.

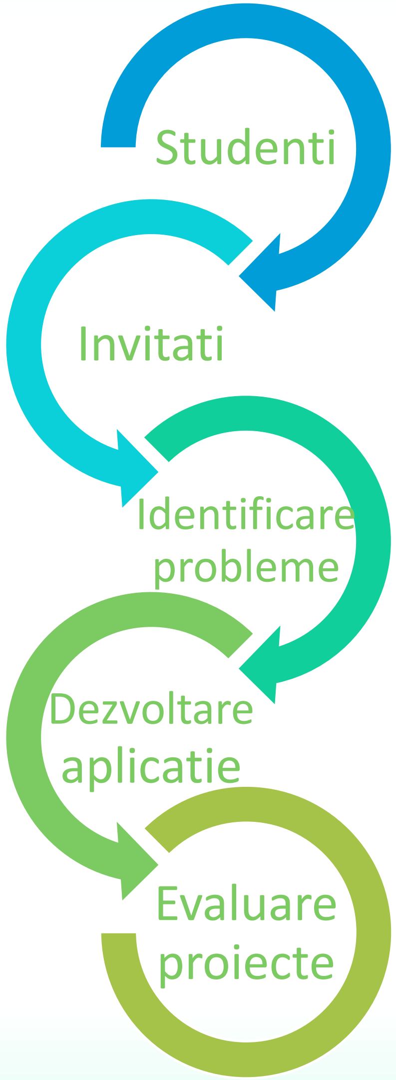
Cum?

Identificare probleme:

- Analiza literaturii existente
- Analiza situatiei din Romania
- Discutii cu invitatii

Metode de IA aplicabile:

- Clustering
- Clasificare
- Detecție outliers
- Predicție/Regresie
- …
- … Orice AI method aplicabilă



Challenge:
Colectare date specifice României

Soluții pentru a limita schimbarea climatica

- Soluții generale:

- Estimari si predictii mai bune
- Monitorizare și urmarire
- Optimizare procese

Metode de IA aplicabile:

- Clustering
- Clasificare
- Detecție outliers
- Predicție/Regresie
- Modelare generativă
- Object recognition
- …

Cursuri similare in alte universități

- Artificial Intelligence for Social Good (University of Southtern, California)
- Data for Sustainable Development (Stanford University)
- Mathematical Modeling with applications to Biology, Climate and Sustainability (Bowdain Colledge, Maine)
- Decision Making in Natural Resource Management (Cornwell University)
- Excursions in Computational Sustainability (Cornwell University)
- Computational Sustainability (Georgia Institute of Technology)
- Design To Impact Climate Change (Carnegie Mellon University)

Abordari din literatura de specialitate (1)

Component of climate change research	Finding or development	Technique used with the standard acronym	References
Climate impacts	Assess the impact of climate change on above-ground biomass.	Support Vector Machines (SVM), Artificial Neural Networks (ANN), Generalised Regression Neural Network (GRNN).	Wu *et al* (2019)
Climate impacts	Assess the impact of climatic change on the global hydrological cycle, with an emphasis on changes in evapotranspiration.	Model Tree Ensemble (MTE).	Jung *et al* (2010)
Climate impacts	Assess the impact of future climate change on hydrology in India, and including for river flow.	Principal Components Analysis (PCA) and fuzzy clustering. Relevance Vector Machine (RVM).	Ghosh and Mujumdar (2008)
Climate impacts	Predict hydrological variables (evapotranspiration) from inputs of meteorological variables (precipitation, temperature) in India.	Fuzzy logic, Least Squares Support Vector Regression (LS-SVR), Artificial Neural Networks (ANN), Adaptive Neuro-Fuzzy Inference System (ANFIS).	Goyal *et al* (2014)

Abordari din literatura de specialitate (2)

Component of climate change research	Finding or development	Technique used with the standard acronym	References
Climate impacts	Determine the impact of water scarcity (drought) in different climatic systems.	Model Tree Ensembles (Random Forests, RF).	Yang *et al* (2016)
Climate impacts	Estimate crop yields from satellite data.	Convolutional Neural Network (CNN). Gaussian Process (GP) Regression.	Azzari *et al* (2017), Burke and Lobell (2017)
Climate impacts	Determine the influence of climate drivers on sand-deposition in semi-arid regions.	Artificial Neural Networks (ANN).	Buckland *et al* (2019)
Climate datasets	Produce a long-term, globally consistent runoff dataset for assessing hydrological trends and variability.	Random Forest (RF).	Ghiggi *et al* (2019)
Climate datasets	Use satellite-based retrievals (PERSIANN) to provide globally consistent estimates of precipitation.	Artificial Neural Network (ANN).	Hsu *et al* (1997), Hong *et al* (2007), Nguyen *et al* (2018)

Abordari din literatura de specialitate (3)

Component of climate change research	Finding or development	Technique used with the standard acronym	References
Climate datasets	Improving estimates of min and max temperatures for incomplete timeseries. Generate better estimates of daily maximum and minimum temperatures, based on information from other nearby measurements and where accurate time of recording is undertaken.	Gaussian Process (GP) model fitted with a Markov Chain Monte Carlo (MCMC) method.	Rischard *et al* (2018)
Climate datasets	Downscale GCM precipitation fields to scales appropriate for impact assessment.	Kernel Regression (KR).	Salvi *et al* (2017)
Climate extremes	Identify extreme weather events in the output of a global climate model.	Convolutional Neural Network (CNN); 3D Convolutional encoder-decoder.	Liu *et al* (2016)
Climate extremes	Predict a drought index using meteorological and climate indices as inputs.	Extreme Learning Machine & Convolutional Neural Network (CNN).	Deo and Sahin (2015)
Climate extremes	Predict meteorological and agricultural drought conditions from satellite data.	Random Forest (RF); Gradient Boosted Regression Trees (GBRT).	Park *et al* (2016)
Climate extremes	Forecast meteorological droughts using antecedent meteorological information in Ethiopia.	Artificial Neural Network (ANN); Support Vector Regression (SVR); Wavelet Transforms.	Mishra and Desai (2006), Belayneh *et al* (2016)

Abordari din literatura de specialitate (4)

Component of climate change research	Finding or development	Technique used with the standard acronym	References
Earth System modelling	Improve convection parameterisations using machine learning emulators.	Artificial Neural Networks (ANN).	Gentine *et al* (2018)
Earth System modelling	Improve the speed of global climate model parameterisations.	Artificial Neural Networks (ANN).	Krasnopolsky *et al* (2005)
Earth System modelling	Emulate climate models to increase the range of parameter values in which a climate model can work.	A range of inversion methods, including Ensemble Kalman inversion and the Markov Chain Monte Carlo (MCMC) algorithm.	Schneider *et al* (2017)
Earth System modelling	Classify land cover from earth observation data (satellites).	Random Forest (RF).	Rodriguez-Galiano *et al* (2012)
Earth System modelling	Identify preferred regions of phase-space for a numerical weather prediction model for the Euro–Atlantic region.	Clustering.	Dawson *et al* (2012)
Earth System modelling	Emulate complex atmospheric models of aerosols to test different potential values of effective parameters.	Gaussian process (GP) emulation.	Lee *et al* (2013)

Abordari din literatura de specialitate (5)

Component of climate change research	Finding or development	Technique used with the standard acronym	References
Teleconnections	Capture the dynamics and structure of the Madden–Julian Oscillation (MJO).	Self-Organising Map (SOM).	Chattopadhyay *et al* (2013)
Teleconnections	Identify terrestrial tropical connections with the Pacific Decadal Oscillation (PDO).	Clustering, empirical orthogonal functions (EOFs).	Yang *et al* (2019)
Teleconnections	Identify SST indices and their impacts on terrestrial climate.	Shared Reciprocal Nearest Neighbours (SRNN), and graph-based approaches.	Liess *et al* (2017)
Weather forecasting	Use AI for post-processing of weather forecasts to aid human forecasters.	Random Forests (RF), Gradient Boosted Regression Trees (GBRT).	McGovern *et al* (2017)
Future climate scenarios	Merge multiple seasonal climate predictions by weighting models by skill.	Bayesian linear regression.	Luo *et al* (2007)
Future climate scenarios	Weighting climate models by their skill produce better performance than ensemble averages.	Generalized Hidden Markov Models (HMM).	Monteleoni *et al* (2011)

AI for Climate Change in 4 possible directions

1. AI for EARTH
    - incendii
    - defrisari

2. AI for ENVIRONMENT
    - biodiversitate
    - poluare

3. AI for AGRICULTURE
    - seceta
    - randament agricol
    - aprovizionare

4. AI for SOCIETY
    - trafic
    - energie regenerabila
    - protectie sociala

AI for Earth 1

Reducing deforestation

ML can be used to:

- differentiate selective cutting from clearcutting using remote sensing imagery [3, 4]
- to detect and report chainsaw sounds within a one-kilometer radius, if there are installed (old) smartphones powered by solar panels in the forest [5].

[3] Matthew G Hethcoat, David P Edwards, Joao MB Carreiras, Robert G Bryant, Filipe M Franca, and Shaun Quegan. A machine learning approach to map tropical selective logging. Remote Sensing of Environment, 221:569–582, 2019.

[4] AGSJ Baccini, SJ Goetz, WSWalker, NT Laporte,MSun, D Sulla-Menashe, J Hackler, PSA Beck, R Dubayah, MA Friedl, et al. Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. Nature climate change, 2(3):182, 2012.

[5] Rainforest connection. https://rfcx.org

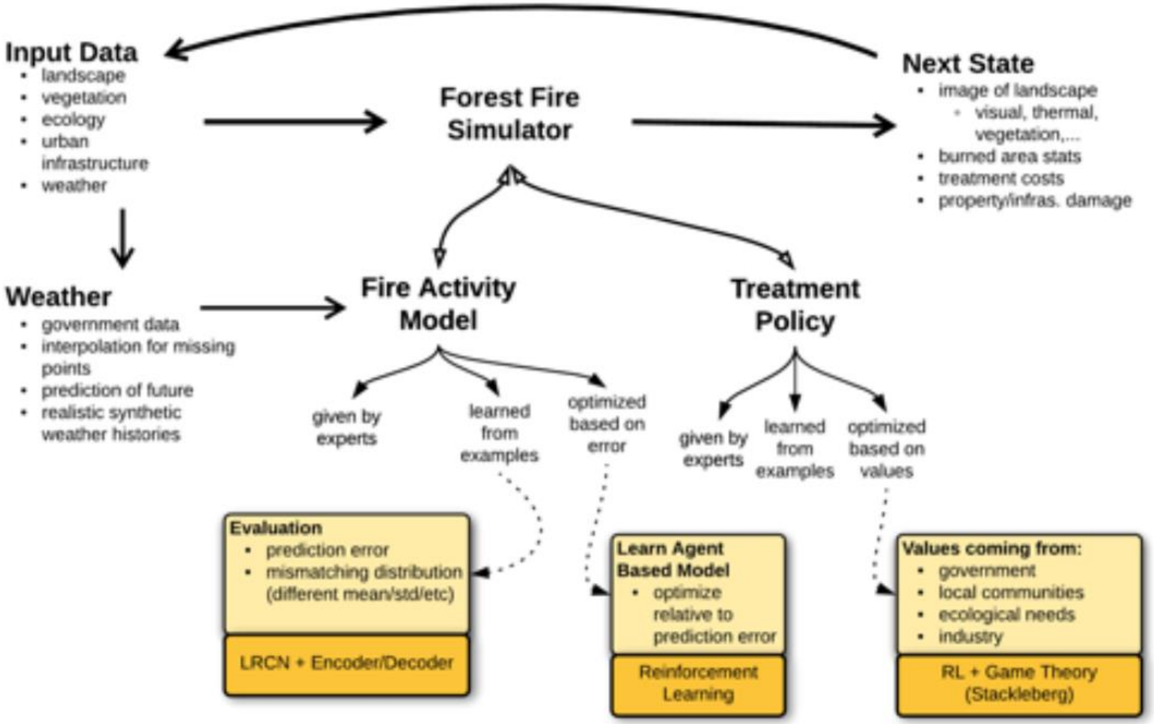
AI for Earth 2

Reducing Forest Fire [6]

ML can help monitor the health of forests

-> predict the risk of fire,

=> contribute to sustainable forestry.



[6] *Adaptation Through Learning Using Machine Learning to Improve Forest Wildfire Management, M. Crowley*

AI for ENVIRONMENT 1

ML is widely used to make **local forecasts** (forecasts are most actionable if they are specific and local) from coarse 10–100 km climate or weather model predictions; various authors have attempted this using support vector machines, auto encoders, Bayesian deep learning, and super-resolution convolutional neural networks [7].

For example, ML **can predict localized flooding patterns from past data** [8], which could inform individuals buying insurance or homes.

Since ML methods like neural networks are effective at **predicting local flooding during extreme weather events** [8], these could be used to update local flood risk estimates to benefit individuals.

[7] Wan Li, Li Ni, Zhao-liang Li, Si-bo Duan, and Hua Wu. Evaluation of machine learning algorithms in spatial downscaling of MODIS land surface temperature. IEEE Journal of Selected Topics in Applied Earth observations and Remote Sensing, 12:2299–2307, 2019.

[8] MC Perignon, P Passalacqua, TM Jarriel, JM Adams, and I Overeem. Patterns of geomorphic processes across deltas using image analysis and machine learning. In AGU Fall Meeting Abstracts, 2018

AI for ENVIRONMENT 2

Monitoring biodiversity

Accurate estimates of species populations are the foundation on which conservation efforts are built. Camera traps and aerial imagery have increased the richness and coverage of sampling efforts.

ML can help infer **biodiversity counts from image-based sensors**. For instance, camera traps take photos automatically whenever a motion sensor is activated – computer vision can be used to classify the species that pass by, supporting a real-time, less labor-intensive species count [9]. It is also possible to use aerial imagery to estimate the size of large herds or count birds [10].

In underwater ecosystems, ML has been used to identify plankton automatically from underwater cameras and to infer fish populations from the structure of coral reefs [11].

ML to identify and **manage sites for geothermal energy**, using satellite imagery and seismic data [12].

[9] Project Zamba computer vision for wildlife research & conservation. https://zamba.drivendata.org/.

[10] Sara Beery, Yang Liu, Dan Morris, Jim Piavis, Ashish Kapoor, Markus Meister, and Pietro Perona. Synthetic examples improve generalization for rare classes. Preprint arXiv:1904.05916, 2019.

[11] Mohammad Sadegh Norouzzadeh, Anh Nguyen, Margaret Kosmala, Alexandra Swanson, Meredith S Palmer, Craig Packer, and Jeff Clune. Automatically identifying, counting, and describing wild animals in camera-trap images with deep learning. Proceedings of the National Academy of Sciences, 115(25):E5716–E5725, 2018.

[12] Energy department awards $5.5 million to apply machine learning to geothermal exploration: https://www.energy.gov/eere/articles/energy-department-awards-55-millionapply-machine-learning-geothermal-exploration.

AI for AGRICULTURE 1

ML can contribute to **precision agriculture**.

Intelligent irrigation systems can save large amounts of water while reducing pests that thrive under excessive moisture [13].

ML can also help in **disease plants/fruits detection**, weed detection, and soil sensing [14].

ML can guide **crop yield prediction** [15] and even macroeconomic models that help farmers predict crop demand and decide what to plant at the beginning of the season [16].

[13] Paul Hawken. Drawdown: The most comprehensive plan ever proposed to reverse global warming. 2015

[14] Konstantinos Liakos, Patrizia Busato, Dimitrios Moshou, Simon Pearson, and Dionysis Bochtis. Machine learning in agriculture: A review. Sensors, 18(8):2674, 2018.

[15] Jiaxuan You, Xiaocheng Li, Melvin Low, David Lobell, and Stefano Ermon. Deep Gaussian process for crop yield prediction based on remote sensing data. In Thirty-First AAAI Conference on Artificial Intelligence, 2017.

[16] Wei Ma, Kendall Nowocin, Niraj Marathe, and George H Chen. An interpretable produce price forecasting system for small and marginal farmers in india using collaborative filtering and adaptive nearest neighbors. In Proceedings of the Tenth International Conference on Information and Communication Technologies and Development, page 6. ACM, 2019.

AI for AGRICULTURE 2

ML can help reduce **food waste by optimizing delivery routes** and improving demand forecasting at the point of sale, as well as improving refrigeration systems [17].

ML can also potentially assist with other issues related to food waste, such as helping develop sensors to identify when produce is about to spoil, so it can be sold quickly or removed from a storage crate before it ruins the rest of the shipment [18].

[17] Antonella Meneghetti and Luca Monti. Greening the food supply chain: an optimisation model for sustainable design of refrigerated automated warehouses. International Journal of Production Research, 53(21):6567–6587, 2015.

[18] Guillermo Fuertes, Ismael Soto, Ra´ul Carrasco, Manuel Vargas, Jorge Sabattin, and Carolina Lagos. Intelligent packaging systems: sensors and nanosensors to monitor food quality and safety. Journal of Sensors, 2016.

AI for SOCIETY 1

ML can **improve public services**, help gather data for decision-making, and guide plans for future development [19].

ML can play a role for decarbonizing transportation that goes much further.

ML can improve vehicle engineering, enable **intelligent infrastructure**, and provide policy-relevant information.

ML can **improve our understanding about passengers' travel mode choices**, which in turn informs transportation planning, such as where public transit should be built [20].

[19] Daisik Nam, Hyunmyung Kim, Jaewoo Cho, and R Jayakrishnan. A model based on deep learning for predicting travel mode choice. In Proceedings of the Transportation Research Board 96th Annual Meeting Transportation Research Board, Washington, DC, USA, pages 8–12, 2017.

[20] Julian Hagenauer and Marco Helbich. A comparative study of machine learning classifiers for modeling travel mode choice. Expert Systems with Applications, 78:273 – 282, 2017.

AI for SOCIETY 2

ML can potentially assist in reducing overall electricity consumption; streamlining factories' heating, ventilation, and air conditioning systems [21].

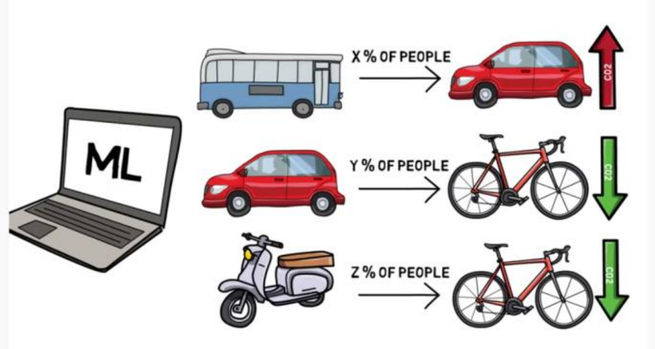
ML can also help solve **the bike sharing rebalancing** problem, where shared bikes accumulate in one location and are lacking in other locations, by improving forecasts of bike demand and inventory [22].

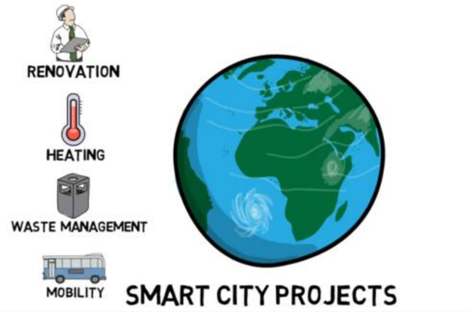
ML can provide tools that help to integrate **bike shares with other modes of transportation**. Many emerging bike and scooter sharing services are dockless, which means that they are parked anywhere in public space and can block sidewalks. ML has been applied to monitor public sentiment about such bike shares via tweets.

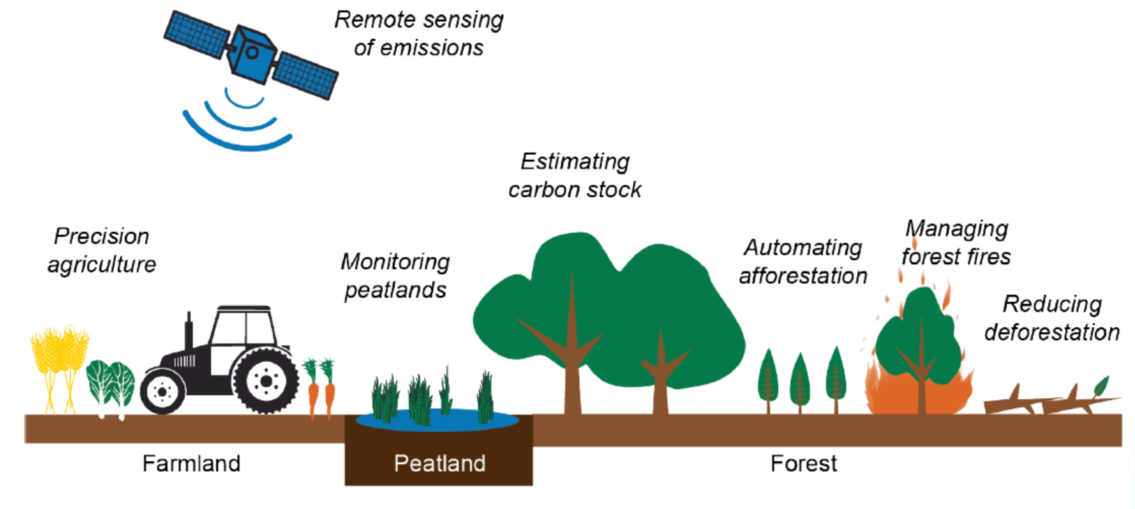
[21] Kenneth Gillingham and James H Stock. The cost of reducing greenhouse gas emissions. Journal of Economic Perspectives, 32(4):53–72, 2018.

[22] Adish Singla, Marco Santoni, G¨ybor Bart´ok, Pratik Mukerji, Moritz Meenen, and Andreas Krause. Incentivizing users for balancing bike sharing systems. In Proceedings of the Twenty-Ninth AAAI Conference on Artificial Intelligence, AAAI'15, pages 723–729. AAAI Press, 2015.

AI pentru limitarea schimbării climatice







Evenimente care au la baza AI pentru umanitate:

- https://www.climatechange.ai/events/neurips2020
- https://crcs.seas.harvard.edu/event/ai-social-good-workshop-2020
- https://www.compsust.net/cogs.php
- https://crcs.seas.harvard.edu/event/workshop_ai_society
- https://aaai.org/Conferences/AAAI-20/
- https://www.climatechange.ai/events/neurips2020
- https://www.samsi.info/programs-and-activities/2019-2020-education-and-outreach-programs-and-workshops/eo-diversity-in-data-science-and-machine-learning-conference-october-17-18-2019/
- https://sites.google.com/usc.edu/kdd19-dmaic-workshop
- https://www.climatechange.ai/
- https://compass.acm.org/
- https://www.ams.org/meetings/sectional/2257_program_ss1.html