Individual assignment: Machine learning and climate change

In 2022, a group with more than 20 researchers in Machine learning published this 96-page overview article:

Rolnick, D, et al., "*Tackling Climate Change with Machine Learning*", ACM Computing Surveys, Vol. 55, 2022.

on how machine learning can be used for the Sustainable Development Goal (SDG) 13: Climate action. The abstract of the article reads:

"*Climate change is one of the greatest challenges facing humanity, and we, as machine learning (ML) experts, may wonder how we can help. Here we describe how ML can be a powerful tool in reducing greenhouse gas emissions and helping society adapt to a changing climate. From smart grids to disaster management, we identify high impact problems where existing gaps can be filled by ML, in collaboration with other fields. Our recommendations encompass exciting research questions as well as promising business opportunities. We call on the ML community to join the global effort against climate change.*"

Table 1 in the article (reproduced below) gives an overview of the sections of the article. The authors have introduced flags for some sections of the article. The blue flag ***High Leverage*** "*denotes bottlenecks that domain experts have identified in climate change mitigation or adaptation and that we believe to be particularly well-suited to tools from ML. These areas may be especially fruitful for ML practitioners...*". The following sections in the article are flagged as ***High Leverage***:

2 ELECTRICITY SYSTEMS
Forecasting supply and demand
Improving scheduling and flexible demand
Accelerating materials science
Accelerating fusion science
Reducing life-cycle fossil fuel emissions
Approaching low-data settings
3 TRANSPORTATION
Modeling demand
Electric vehicles
Enabling low-carbon options
4 BUILDINGS & CITIES
Smart buildings
Gathering infrastructure data
Data for smart cities
5 INDUSTRY
Reducing food waste
Climate-friendly construction
Climate-friendly chemicals
Adaptive control
Using cleaner electricity
6 FARMS & FORESTS
Remote sensing of emissions
Precision agriculture
Monitoring peatlands
Estimating carbon stock
Reducing deforestation
7 CARBON DIOXIDE REMOVAL
7.2 Sequestering CO2
8 CLIMATE PREDICTION
Clouds and aerosols
Ice sheets and sea level rise
Local Forecasts
9 SOCIETAL IMPACTS
Monitoring ecosystems
Monitoring biodiversity
Maintaining infrastructure
Food security
Disaster response
10 SOLAR GEOENGINEERING
Engineering a control system
11 INDIVIDUAL ACTION
Facilitating behavior change
12 COLLECTIVE DECISIONS
Gathering data
Evaluating policy effects
14 FINANCE
Climate analytics

For this individual assignment you shall follow these five steps:

1. Select a section of the article which includes a ***High Leverage*** area according to the list above, e.g., “3 Transportation” or “9 Societal impacts”.

2. Within your selected section, you shall select one of the ***High Leverage*** areas, e.g., “***Electric vehicles***” or “***Food security***”,

3. Read and summarize your selected ***High Leverage*** area in one of the text boxes below.

4. Select one of the articles cited in your selected ***High Leverage*** area and summarize your reflections on this article in one of the text boxes below. It is important that the article you select in some way illustrates or demonstrates the use of machine learning in your selected ***High Leverage*** area, e.g., articles [158] and [586] in ***Modeling demand*** in the Transportation section.

5. Read the Conclusion section of the article and provide your own reflection in one of the text boxes below on the authors’ conclusions regarding climate change and machine learning.

Reflection question 1: Summarize your selected *High Leverage* area and explain why you have selected this area.

I was hoping for some more evolved Machine Learning techniques in fighting deforestation and in measuring forest’s efficacy in reducing CO_2 in contrast to tree plantations. However, I chose Production and Energy instead, since that is an area which is in great need of adaptation to a more climate friendly world, as well as a major contributor to the ongoing climate change. I, because of this, chose the area of Adaptive control.

This is mainly concerning heat, ventilation and air conditioning systems (HVAC) but I do not see why it would not be applicable to a much wider area in optimising and improving the efficiency as well as minimising the Energy consumption by a product. By combining machine learning and optimisation the emission of green house gases can be decreased significantly. Google and Deep Mind have used this technique to reduce cost and energy consumption as well as reduce the climate impact of Google’s servers. Adaptive control can also be used in multiple sectors, helping lower the climate impact of each sector in this way.

Reflection question 2: Summarize your selected article from your High Leverage area: What methods are the author(s) using? What are the conclusions? What further work would be needed to advance the area?

I choose reference [202]. The authors are using methods such as multivariate regression and dimensionality reduction algorithms, with regression trees and time delay neural networks. The motivation of using these are their easy implementation; that they are easy to be used even for untrained workers when using it in place of their current rule based controllers. Compared to model predictive control, their approach shows a decrease in complexity while keeping the efficiency seen when using the model predictive control (that is often used). Hence, they are helping industries lowering their emissions of green house gases while not costing them extra time nor money when replacing the rule based controller by this technique. It is a “multiple-input-multiple-out” control problem which is often seen in building sectors. A tuneable “feature selection” method was used to decrease complexity and cost. This was used on multiple buildings to control the temperature. More tests are welcome, and perhaps in different sectors and other usages would be a great contribution to the knowledge of the area of applications.

Reflection question 3: What are your main takeaways from section 15 Conclusion?

My main takeaways are that Machine Learning (ML) can contribute to a more climate friendly world if it is used with care, otherwise it can be the opposite. ML has the potential to help humanity to take a leap towards the zero emission goals., thus its importance cannot be stressed too much. Also, in the proceeding of trying to reduce climate impact by the use of ML, our knowledge of ML will plausibly increase. It is also of importance that data sets are used for the right purpose, adapting data to the area of application. If applicable somewhere in the world does not imply it is applicable somewhere else, even though it might be within the same sector. Social factors and other constraints always play a role when deciding the usage and applicability of ML and data sets. In order to attack the problems within climate change with the use of ML one should observe, listen, collaborate and look for complications and bottlenecks rather than expect to always come up with some revolutionary idea without knowing what problems that is in need of solutions.

Table 1: Climate change solution domains, corresponding to sections of the article, matched with selected areas of ML that are relevant to each.

		Causal inference	Computer vision	Interpretable models	NLP	RL & Control	Time-series analysis	Transfer learning	Uncertainty quantification	Unsupervised learning
Mitigation	**Electricity systems**									
	Enabling low-carbon electricity		•	•		•	•		•	•
	Reducing current-system impacts		•				•		•	•
	Ensuring global impact		•					•		•
	Transportation									
	Reducing transport activity		•				•		•	•
	Improving vehicle efficiency		•			•				
	Alternative fuels & electrification					•				•
	Modal shift	•	•				•		•	
	Buildings and cities									
	Optimizing buildings	•				•	•	•		
	Urban planning		•				•	•		•
	The future of cities				•			•	•	•
	Industry									
	Optimizing supply chains		•			•	•			
	Improving materials									•
	Production & energy		•	•		•				
	Farms & forests									
	Remote sensing of emissions		•							
	Precision agriculture		•			•	•			
	Monitoring peatlands		•							
	Managing forests		•			•	•			
	Carbon dioxide removal									
	Direct air capture									•
	Sequestering CO_2		•						•	•
Adaptation	**Climate prediction**									
	Uniting data, ML & climate science		•	•			•		•	
	Forecasting extreme events		•	•			•		•	
	Societal impacts									
	Ecology		•					•		
	Infrastructure					•	•		•	
	Social systems		•				•			•
	Crisis		•		•					
	Solar geoengineering									
	Understanding & improving aerosols						•		•	
	Engineering a control system					•			•	
	Modeling impacts						•		•	
Tools for Action	**Individual action**									
	Understanding personal footprint	•			•	•	•			
	Facilitating behavior change				•					•
	Collective decisions									
	Modeling social interactions			•		•				
	Informing policy	•	•		•				•	•
	Designing markets					•	•			•
	Education				•	•				
	Finance				•		•		•	