American Journal of Preventive Cardiology 19 (2024) 100707

Contents lists available at ScienceDirect

American Journal of Preventive Cardiology

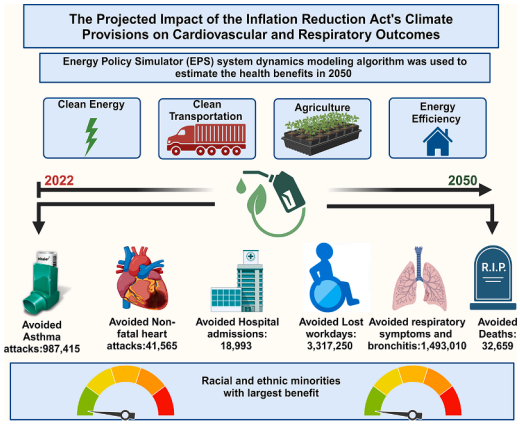
journal homepage: www.journals.elsevier.com/american-journal-of-preventive-cardiology

The projected impact of the inflation reduction act's climate provisions on cardiovascular and respiratory outcomes

Ashish Kumar [a], Sourbha Dani [b], Ajay Sharma [b], Sumanth Khadke [b], Martha Gulati [c], Sanjay Rajagopalan [d], Sadeer G. Al-Kindi [e,1], Sarju Ganatra [b,1,*]

[a] Department of Medicine, Cleveland Clinic Akron General, Akron, OH, USA
[b] Department of Cardiovascular Medicine, Department of Medicine, Landsman Heart and Vascular Center, Lahey Hospital and Medical Center, Beth Israel Lahey Health, 41 Mall Road, Burlington, MA 01805, USA
[c] Barbra Streisand Women's Heart Center, Cedars Sinai Medical Center, Smidt Heart Institute, Los Angeles, CA, USA
[d] Division of Cardiovascular Medicine, Harrington Heart and Vascular Institute, University Hospitals and Case Western Reserve University, Cleveland, OH, USA
[e] Department of Cardiovascular Medicine, Houston Methodist Hospital, Houston, TX, USA

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Environmental pollution
Inflation reduction act (ira)
Nationally determined contribution (ndc) plan
greenhouse gas
health outcomes

ABSTRACT

Onjective: Climate change and environmental pollution have known health effects. The recently introduced inflation reduction act (IRA) by the United States government includes funding initiatives to curb climate change, and reduce environmental pollution, in line with the nationally determined contribution (NDC) plan (40–50 % reduction in greenhouse gas [GHG] emissions by 2030, as compared with 2005). The projected cardiovascular health benefits of the IRA driven climate actions to achieve the NDC goals are not known.
Methods: We used the Energy Policy Simulator (EPS), a simulation algorithm based on systems dynamics modelling estimating the impact of various energy policies, to model the impact of achieving NDC targets in the

Funding: None
* Corresponding author.
E-mail address: Sarju.Ganatra@Lahey.org (S. Ganatra).
[1] Equal contributors

https://doi.org/10.1016/j.ajpc.2024.100707
Received 9 January 2024; Received in revised form 8 May 2024; Accepted 9 July 2024
Available online 10 July 2024

United States on health outcomes by 2050. We further investigated race-specific impact on mortality (absolute and relative) by 2050.We estimated the projected reduction in six adverse health outcomes between 2022 and 2050: asthma attacks, non-fatal heart attacks, hospital admissions, respiratory symptoms and bronchitis, lost workdays, and deaths.

Results: Achievement of NDC targets by 2050 will result in 987,415 avoided asthma attacks, 41,565 avoided nonfatal heart attacks, 18,993 avoided hospital admissions, 1,493,010 avoided respiratory symptoms and bronchitis, 3,317,250 avoided lost workdays, and 32,659 avoided deaths (22,839 among white individuals, 4993 among Black individuals, 2801 among Asian individuals, and 2026 among other/multirace individuals). By 2050, minority racial groups had higher relative change in avoided deaths (white -0.74 %, Black -1.01 %, Asian -1.24 %, and other/multirace -1.75 %). Similarly, Hispanics/latinos higher relative reductions in deaths (-1.4 %) compared with non-Hispanic/Latinos (-0.7 %) by 2050.

Conclusion: The IRA facilitated achievement of NDC GHG reduction goals by 2050 would result in substantial number of avoided adverse health outcomes and death. Racial and ethnic minorities are expected to have the largest relative reductions in deaths by 2050. The current report underscores the importance of continued climate action investment irrespective of political differences. The appreciation of this aspect of the IRA may be more important to overall preservation of health, beyond the reduction in medication costs.

Abbreviations

IRA	inflation reduction act
GHG	green house gas
EPS	energy policy simulator
NDC	nationally determined contributions

1. Introduction

The impact of changing climate on human health is becoming increasingly evident [1,2]. Extreme weather events are disrupting lives and livelihood across the globe. Robust evidence demonstrates the linkage between climate change and environmental pollution with disease, including asthma, atherosclerosis, myocardial infarction, among others and with overall mortality [3]. The global burden of disease study estimates that environmental pollution accounts for 9 million global deaths annually, which makes it one of the leading causes worldwide [4]. Additionally, with worsening climate change, more people are facing consequence of connected cascading events such as, wildfires, hurricanes, floods, and forced migration globally from failed crops, droughts, and resulting political unrest [3].

In August 2022, the United States government passed the Inflation Reduction Act (IRA), which includes $369 billion in funding for climate and clean energy provisions such as clean energy and electric vehicle tax credits to large-scale investments in domestic manufacturing of clean technologies and environmental justice. The climate and tax law provides $281 million to state agencies to improve air quality monitoring, and there are other measures to promote environmental justice. The IRA is the most significant federal climate and clean energy legislation in United States history, and its provisions aiming to reduce greenhouse gas (GHG) emissions. We, therefore, sought to examine the long-term impact of IRA environmental provisions on population health outcomes and related costs.

2. Methods

We used the Energy Policy Simulator (EPS), an open-source dynamics computer model created in Vensim, a tool produced by Ventana Systems, for the simulation of system dynamics models. Vensim is a simulation software used to simulate system interactions a variety of contexts using causal loop or stock and flow diagrams. In Vensim by establishing causal relationships among system variables using causal loop diagrams and stock and flow diagrams including the mathematical relationship one can estimate the system impact of an intervention in a complex system. This has been explained in detail under the model component section of EPS documentation where each of the stock and flow diagrams used in EPS is described [5]. The EPS uses multiple input data and allows one to control numerous different policies that affect energy use and emissions in various sectors of the economy, including transportation, buildings, electricity supply, industry, agriculture, land use, forestry, etc. It also includes various smaller components, such as district heat, and hydrogen supply, cross-sector, research and development, and government revenue accounting. The model reports outputs at annual intervals. Accounting for these factors, the EPS provides numerous outputs estimating the environmental, economic, and human health impacts. This is compared with the business as usual model generated from prior study results as input data. As described earlier, EPS is based on a theoretical framework called system dynamics, where energy use and economy are viewed as an open, ever-changing, non-equilibrium system. The system dynamics model includes “stocks” or variables, value of which are affected by flow into and out of these variables. Further, the system dynamics models uses the output of the previous time step as an input of the next time step. The model structure in EPS consists of visible structure pertaining to the equations that define relationships between variables and behind the scene structure which contain data and are acted on by the equations. Further, the EPS model has been structured to avoid double counting of model effects. Finally, an advantage of a systems dynamics model is that the simulation could be conextualized with input from humans that cannot be accounted for by a computer model. Therefore the EPS model provides the best possible prediction of outcomes avoiding overfitting [5]. All analyses were limited to the United States.

We estimated the potential health benefits of Nationally Determined Contributions (NDC) policies if implemented by the United States, facilitated by the IRA, which proposed GHG emission reduction by 50 % below the 2005 levels by year 2030. The NDC was determined by the United States as a part of the Paris Agreement established with a goal of restricting the global rise in temperature to less than 2 °C below the pre-industrial levels and efforts limit temperature rise to 1.5 °C. We estimated the projected reduction in six adverse health outcomes between 2022 and 2050 with full and partial (50 %) implementation of NDC goals: non-fatal myocardial infarctions, asthma attacks, hospital admissions, respiratory symptoms and bronchitis, lost workdays, and deaths. Death data was also examined by race (white, Black, Asian, other/multirace) and ethnic groups (Hispanic/Latino vs not Hispanic/Latino) both in absolute and relative estimates. Avoided deaths were also examined by sector of emission. The EPS calculates the health benefits using “reduced-form tools” published by the United States Environmental Protection Agency. In short, the tools model the health benefits from changes in pollutant emission. The “reduced-form tools” calculates the public health impact of emissions reduction and the results are comparable to the “full-form model” more commonly used by the United States Environmental Protection Agency. We additionally estimated the monetization of health (predominantly premature mortality since this constitutes 97 % of the monetized benefit) and climate benefits based on the Value of a Statistical Life (VSL) and the Social Cost

of Carbon, respectively. Both the input and output data from the EPS model lacks numerical uncertainty bounds, given the complexity of the model calculation.

Interventions that were not a part of NDC policies were not accounted for in the present analysis. Further, we did not alter the implementation schedule, and it was kept in line with the NDC policies. The present analysis was performed in November 2022. The EPS has been used and validated in previous studies [6–8]. The present study was deemed exempt from the institutional review board approval, as the study did not include human subjects and was based on mathematical models for prediction.

3. Results

With complete implementation of the proposed climate-related policy interventions and investments, there would be 987,415 avoided asthma attacks [with 50 % implementation of NDC 393, 476], 41,565 avoided nonfatal myocardial infarctions [with 50 % implementation of NDC 16, 528], 18,993 avoided hospital admissions [with 50 % implementation of NDC 7711] (Fig. 1A), 1493,010 avoided respiratory symptoms and bronchitis[with 50 % implementation of NDC 595, 555], and 3317,250 avoided lost workdays [with 50 % implementation of NDC 1, 325, 670], by year 2050. All numbers of avoided death and other outcomes reported in this study are for year 2050 alone and not an cummunlaitve number until year 2050.

A total of 32,659 deaths (22,839 among white individuals, 4993 among Black individuals, 2801 among Asian individuals, and 2026 among other/multirace individuals) would be avoided by year 2050, which would be - 0.80 % change in mortality in the year 2050, compared with business-as-usual [estimated ~ 4, 082,375 deaths in 2050]. With

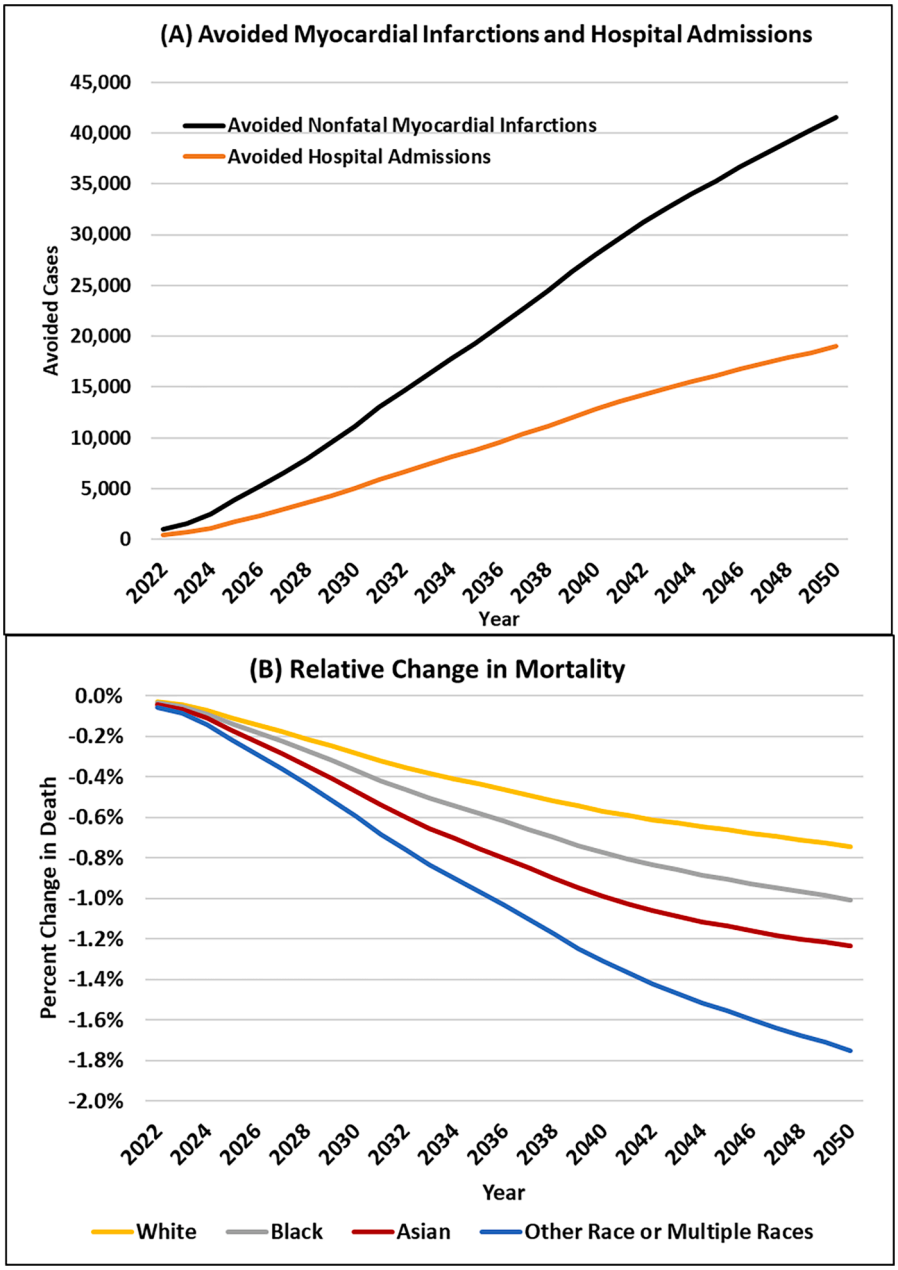


Fig. 1. Line graph for avoided health outcomes: Projected estimations of avoided adverse health outcomes with achievement of NDC goals 2022–2050 (A) Avoided non-fatal myocardial infarction and avoided hospital admissions; (B) percent change in death by race. Minority racial groups had higher relative change in avoided deaths.

50 % implementation of the NDC policies, there would be 13,293 deaths avoided by year 2050. By 2050, minority racial groups had higher relative change in avoided deaths (white −0.74 %, Black −1.01 %, Asian −1.24 %, and other/multirace −1.75 %, Fig. 1B). Similarly, Hispanics/latinos higher relative reductions in deaths (−1.40 %) compared with non-Hispanic/Latinos (−0.70 %) by 2050. The vast majority of deaths were avoided via Building Component Electrification (9245 deaths, 28.30 %), EV Sales Standard (8164 deaths, 25 %) and Electrification + Hydrogen (6493 deaths, 19.90 %). Altogether, a total of $1888 billion (2020 US dollars) would be saved (monetized avoided deaths and climate change costs) by 2050, with full implementation of the policies. We estimate $541 billion in savings (2020 US dollars) with 50 % implementation of the NDC, by 2050.

4. Discussion

We demonstrate that the implementation of the climate policies embedded in the IRA 2022 in line with NDC goals can lead to substantial public health benefits across various disease domains. Importantly, the mortality benefits seem to be larger in racial and ethnic minorities, which is expected to reduce mortality disparities in the US. The cost savings of the program more than offset the IRA investment even under a 50 % implementation scenario, by the year 2050.

Prior studies have indicated a substantial climate impact in vulnerable populations (e.g. low income individuals, elderly, and people with chronic conditions) [9,10]. Our findings suggest that meeting the NDC goals as described in the IRA, would result in a large benefit in minority communities and would help drive equitable health outcomes in marginalized communities. This differential benefit could be attributed to large burden of adverse environmental exposures in marginalized populations, and resultant higher benefit from directed policies, providing benefits for energy efficient home upgrades and clean energy tax credits in these same populations.

Our analysis also suggests that the cost savings related to health benefits ($1888 billion) by 2050, would more than obviate the investment in the IRA environmental provisions ($369 billion). Prior experience in legally mandated pollution control programs have demonstrated that these are highly cost-effective. A single dollar invested in air pollution control since 1970 is estimated to have yielded a benefit of $30 (95 %CI: $4–88), a return of $1.5 trillion against an investment of $65 billion overall [11]. Thus the potential benefit seen in the IRA will be cost-effective in the long run and will be highly effective solutions to further the cause of climate inequity for the most vulnerable populations.

The highest benefit in terms of avoided death is achieved by building component electrification, followed by EV sales and by selected industry switching fuels used by their facilities to electricity and/or hydrogen. Climate friendly actions in these three sectors alone may help achieve > 50 % of the projected avoided deaths in the United States by 2050.

With the United States presidential election scheduled for 2024 and a sense of disagreement with regards to IRA across political lines, the possibility of IRA disinvestment is a possibility. Multiple concerns have already been raised regarding the economic and overall value of investment in IRA. Part of the problem could be attributed to the lack of detailed projected health benefits of the IRA and NDC and hence, quantification of such benefits from IRA is currently relevant. In case the IRA is repealed, we will fall back to "Business As Usual" for climate policies leading to loss of all projected health benefits. The current study helps to underscore both the economic and monitory benefit of the planned IRA implementation and hence aid policy makers in their future directions.

There are several limitations to our analysis. First, all the details regarding the intended climate actions of the IRA are not fully available. However, it is geared toward achieving the NDC goals, and we have incorporated these in our analysis. Second, our analysis assumes the actual full implementation of policy actions. Needless to say that the trajectory/timing of policy implementations may significantly affect our estimations. Further, results for only two scenarios (full and 50 % implementation of IRA) were presented in the current analysis, while the projected health benefit might vary based on the level of implementation of IRA. Third, many of the policy decisions are tightly linked, and although our estimations provide general guidance, many of these changes can only happen when examined as a system and assessment of their interdependent impact or out of sequence may result in very different estimates. Fourth, in order to create a computational model that is less complex than the real world, a number of key assumptions needs to be made which may not accurately reflect uncertainties on the ground. The effect of IRA implementation stratified by social determinants of health of regions was not accounted for in the current analysis. Finally, the reported higher health benefit among racial and ethical minorities could be second to relative smaller population size and associated statistical impressions.

5. Conclusion

Achievement of the IRA facilitated NDC GHG reduction goals would lead to substantial number of avoided adverse health outcomes and deaths. Racial and ethnic minorities are expected to have the largest relative reductions in deaths by 2050. Regardless of the election outcomes and the destiny of the IRA in its entirety, we argue that continuation and even further intensification of the IRA climate policies to achieve the NDC goals is crucial.

CRediT authorship contribution statement

Ashish Kumar: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Formal analysis, Data curation. **Sourbha Dani:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Data curation, Conceptualization. **Ajay Sharma:** Writing – original draft, Supervision, Methodology, Conceptualization. **Sumanth Khadke:** Writing – original draft, Visualization, Methodology, Data curation, Conceptualization. **Martha Gulati:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Sanjay Rajagopalan:** Writing – original draft, Supervision, Methodology, Conceptualization. **Sadeer G. Al-Kindi:** Writing – original draft, Supervision, Methodology, Conceptualization. **Sarju Ganatra:** Writing – review & editing, Writing – original draft, Supervision, Software, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

None

References

[1] Rocque RJ, Beaudoin C, Ndjaboue R, et al. Health effects of climate change: an overview of systematic reviews. BMJ Open 2021;11(6):e046333. https://doi.org/10.1136/bmjopen-2020-046333.
[2] Ganatra S, Dani SS, Al-Kindi SG, Rajagopalan S. Health care and climate change: challenges and pathways to sustainable health care. Ann Intern Med 2022;175(11):1598–600. https://doi.org/10.7326/M22-1241.
[3] Khraishah H, Alahmad B, Ostergard RL, et al. Climate change and cardiovascular disease: implications for global health. Nat Rev Cardiol 2022;19(12):798–812. https://doi.org/10.1038/s41569-022-00720-x.
[4] Fuller R, Landrigan PJ, Balakrishnan K, et al. Pollution and health: a progress update. Lancet Planet. Health 2022;6(6):e535–47. https://doi.org/10.1016/S2542-5196(22)00090-0.
[5] Introduction | energy policy simulator documentation. https://docs.energypolicy.solutions/. Accessed June 7, 2023.

[6] Gallagher KS, Zhang F, Orvis R, Rissman J, Liu Q. Assessing the policy gaps for achieving China's climate targets in the Paris agreement. Nat Commun 2019;10(1):1256. https://doi.org/10.1038/s41467-019-09159-0.
[7] Skoczkowski T, Bielecki S, Węglarz A, Włodarczak M, Gutowski P. Impact assessment of climate policy on Poland's power sector. Mitig Adapt Strateg Glob Chang. 2018;23(8):1303–49. https://doi.org/10.1007/s11027-018-9786-z.
[8] Abhyankar N, Lin J, Kahrl F, et al. Achieving an 80% carbon-free electricity system in China by 2035. iScience 2022;25(10). https://doi.org/10.1016/j.isci.2022.105180.
[9] Josey KP, Delaney SW, Wu X, et al. Air Pollution and mortality at the Intersection of race and social class. N Engl J Med 2023;388(15):1396–404. https://doi.org/10.1056/NEJMsa2300523.
[10] Deguen S, Amuzu M, Simoncic V, Kihal-Talantikite W. Exposome and social vulnerability: an overview of the literature review. Int J Environ Res Public Health 2022;19(6). https://doi.org/10.3390/ijerph19063534.
[11] Benefits and costs of the clean air act 1990-2020. Report documents and graphics | US EPA. https://www.epa.gov/clean-air-act-overview/benefits-and-costs-clean-air-act-1990-2020-report-documents-and-graphics. Accessed June 5, 2023.