Lancet Countdown indicators for Italy: tracking progress on climate change and health

Gli indicatori di *Lancet* Countdown per l'Italia: monitorare i cambiamenti climatici e la salute

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RIASSUNTO
Obiettivi: fornire prove degli impatti sulla salute dei cambiamenti climatici in Italia.
Disegno: studio descrittivo.
Setting e partecipanti: gli indicatori pubblicati nel rapporto 2022 di *Lancet* Countdown sono stati adattati e rifiniti per fornire i dati più recenti rilevanti per l'Italia.
Principali misure di outcome: sono stati misurati 12 indicatori, organizzati in cinque sezioni che rispecchiano quelle del rapporto *Lancet* Countdown 2022: impatti, esposizioni e vulnerabilità dei cambiamenti climatici; adattamento, pianificazione e resilienza per la salute; azioni di mitigazione e co-benefici sanitari; economia e finanza; impegno pubblico e politico.
Risultati: i 12 indicatori mostrano un quadro complessivo che rivela due risultati principali. Per prima cosa, il cambiamento climatico sta già incidendo sulla salute della popolazione italiana, con effetti non uniformemente distribuiti nel Paese e con rischi spropozionatamente alti per i gruppi più vulnerabili. Secondo, i risultati mostrano che la mitigazione dei cambiamenti climatici in Italia è stata solo parziale, con costi maggiori per la salute umana. Un'accelerazione nella mitigazione dei cambiamenti climatici attraverso la decarbonizzazione del sistema energetico e il passaggio a modalità di trasporto più sostenibili potrebbe offrire importanti benefici alla salute grazie a un'aria più pulita a livello locale, a stili di vita più attivi e ai cambiamenti climatici grazie alla riduzione del riscaldamento globale. Allo stesso modo, la decarbonizzazione dei sistemi agricoli offrirebbe co-benefici sanitari alla popolazione italiana.
Conclusioni: accelerando le azioni di mitigazione dei cambiamenti climatici, l'Italia ha l'opportunità di apportare importanti e immediati benefici per la salute della sua popolazione. Lo sviluppo di indicatori locali per monitorare gli impatti dei cambiamenti climatici e valutare le azioni di risposta, in termini di adattamento e mitigazione, potrebbe essere utile per guidare e migliorare le azioni e le politiche di contrasto al cambiamento climatico.
Parole chiave: cambiamento climatico, co-benefici, salute globale, ondate di calore, dieta, inquinamento atmosferico

Abstract
Objectives: to provide evidence of the health impacts of climate change in Italy.
Design: descriptive study.

Setting and participants: the indicators published in the 2022 *Lancet* Countdown report were adapted and refined to provide the most recent data relevant to Italy.
Main outcome measures: twelve indicators were measured, organized within five sections mirroring those of the 2022 *Lancet* Countdown report: climate change impacts, exposures, and vulnerabilities; adaptation, planning, and resilience for health; mitigation actions and health co-benefits; economics and finance; and public and political engagement.
Results: the overall picture depicted by the analysis of the 12 indicators reveals two key findings. First, climate change is already affecting the health of Italian populations, with effects not being uniform across the Country and with the most vulnerable groups being disproportionately at risk. Second, results showed that Italy's mitigation response has been partial, with major costs to human health. Accelerated climate change mitigation through energy system decarbonisation and shifts to more sustainable modes of transport could offer major benefits to health from cleaner air locally and from more active lifestyles, and to climate change from reduction of global warming. The decarbonisation of agricultural systems would similarly offer health co-benefits to Italian population.
Conclusions: through accelerated action on climate change mitigation, Italy has the opportunity of delivering major and immediate health benefits to its population. Developing a key set of local indicators to monitor the impacts of climate change and evaluate response actions, in terms of adaptation and mitigation, can help support and enhance policy and action to fight climate changes.
Keywords: climate change, co-benefits, global health, heatwaves, diet, air pollution

What is already known

* Climate change has profound impacts on the physical and social determinants of health around the World.
* Italy's intrinsic hydrogeological vulnerability, its high ecological footprint, the high proportion of elderly and of people living in urban settings make the Italian population particularly vulnerable to the impacts of climate change.
* Climate change mitigation has the potential to deliver enormous health dividends if health is prioritised in all policies

What this study adds

* The negative impacts of climate change are already taking their toll on the health of the Italian population.
* Risks and health effects are unevenly distributed geographically with the most vulnerable groups being most at risk.
* Italy has the opportunity of delivering major and immediate health benefits to its population by accelerating climate change mitigation through energy and agricultural systems decarbonisation and shifts to more sustainable modes of transport as well as enhancing health adaptation measures to increase resilience to climate change and extreme events.

INTRODUCTION

As a result of the ever-increasing emission of greenhouse gases, in 2021 the World was 1.1°C warmer than in the pre-industrial period.[1] This climatic change is already having profound impacts on the physical and social determinants of health around the World, with more frequent and extreme weather events, increased wildfire risk, sea level rise, changes to environmental suitability for infectious disease transmission, and impairments to the natural systems which human health depends on. In order to prevent the most catastrophic impacts of accelerated warming, countries committed to limiting global warming to "well below 2°C", above the pre-industrial (1850-1900) levels, by the end of the century in the 2015 landmark Paris Agreement. However, 7 years on, little progress has been done. Average global temperature has risen by 1.1ºC so far, according to the World Metereological Organization (WMO) and the latest Intergovernmental Panel on Climate Change (IPCC) report warned that the World is set to reach the 1.5ºC level within only the next two decades unless drastic actions are taken.[2,3] Therefore, in the United Nation (UN) Climate Change Conference in Glasgow (COP26), countries reaffirmed the Paris Agreement goal of limiting the increase in the global average temperature to well below 2°C above pre-industrial levels and, recognizing that the impacts of climate change will be much lower at a temperature increase of 1.5 °C compared with 2 °C, engaged in pursuing efforts to limit it to 1.5 °C.

In Europe, summer 2022 was the second hottest on record at about 1.6ºC above 1991-2020 average, with southern parts of the continent most affected.[4] In particular, Italy's intrinsic hydrogeological vulnerability, its high proportion of elderly and urban populations and its high ecological footprint make it vulnerable to the impacts of climate change and put the health of its populations at risk.

Ambitious climate change mitigation holds the potential to deliver enormous health dividends if health is prioritised in all policies. This is not only due to the reduction in climate-related health risks, but especially due to the immediate health co-benefits that climate action could provide: some examples can be how shifting to low-carbon diets would improve health by increasing plant-based food consumption and reducing that of red meat[5,6] while increasing urban greenspace coverage would provide cleaner urban air, as well as a space for social interaction and outdoor recreation.[7,8] Indeed, putting health at the centre of all climate change policies could result in millions of lives saved annually around the World, by 2040.[9] For all these benefits, the Word Health Organization (WHO) considered the 2015 the landmark Paris Agreement as "the most important public health agreement of the century".[10]

AIM AND METHODS

This chapter aims to provide evidence of the health impacts of climate change in Italy and the implications of the Country's response on the health of its inhabitants by adapting and refining the indicators published in the 2022 global *Lancet* Countdown report, to provide data relevant to Italy. "The *Lancet* Countdown: tracking progress on health and climate change" is an international research collaboration created to monitor the health dimensions of climate change and provide sound, scientific evidence to inform policy discussions that keep health at their centre.[11] It draws on the expertise of leading experts from academic and United Nations institutions around the World, and annually reports its findings through indicators published in the medical journal *The Lancet*. While the collaboration reports findings primarily at a global level, national-level data is available for most of its indicators. The study of the national data offers the opportunity to increase our knowledge of the impacts and risks of climate change that largely vary at the local level. Therefore, in this report, out of the 43 indicators in the 2022 global *Lancet* Countdown report,[12] we present 12 indicators for Italy organized within five sections mirroring those of the *Lancet* Countdown: **1.** climate change impacts, exposures, and vulnerabilities; **2.** adaptation, planning, and resilience for health; **3.** mitigation actions and health co-benefits; **4.** economics and finance; **5.** public and political engagement. These indicators have been selected based on availability of extracting national data for Italy from the *Lancet* Countdown indicators. For each indicator, we reported a brief description of the methods, while a detailed description can be found in the Supplementary Material of the 2022 global *Lancet* Countdown report.[12]

SECTION 1. CLIMATE CHANGE IMPACTS, EXPOSURE, AND VULNERABILITY

These indicators are aimed at providing evidence of current climate change in terms of environmental exposure changes and health impacts and population vulnerability.
For Italy, three indicators were defined and are briefly described below.

Exposure of vulnerable populations to heatwaves

Using data from the 2022 global *Lancet* Countdown report (indicator 1.1.2),[12] this indicator estimates the total number of days adults aged over 65 and children aged 0-1 years old were exposed to heatwave events across Italy. For the purpose of this indicator, heatwaves were defined in alignment with the World Meteorological Organization and the definition used in the *Lancet* Countdown report, as a period of at least two days where both the daily minimum and maximum temperatures are above the 95th percentile of the observed in the 1986-2005 period, at a 0.25 x 0.25 degree geographical resolution.[13,14]

Drought

This indicator, adapted from the 2022 global *Lancet* Countdown report (indicator 1.2.2),[12] tracks the percentage of land area in Italy affected by at least one month of drought, defined through the 6-monthly Standardised Precipitation Evapotranspiration Index (SPEI6). The SPEI captures changes in precipitation and the effect of temperature on evaporation and moisture loss. For the purposes of this indicator, extreme drought is defined as SPEI $\leq$-1.6, and exceptional drought as SPEI $\leq$-2, in agreement with the definitions of the Federal Office of Meteorology and Climatology meteoSwiss.[15]

Climate suitability for infectious disease transmission

This indicator tracks the environmental suitability for dengue transmission. It employs a model that incorporates the influence of temperature and rainfall on vectorial capacity and vector abundance and overlays it with human population density data to estimate its basic reproduction potential (R_0) using data from the 2022 global *Lancet* Countdown report, details of the methodology are reported in the Lancet Supplementary Appendix 5.[12] Indicator 1.3.1 shows the change in R_0 defined by the climate, between two periods (1951-1960 and 2012-2021) in Italian regions.

SECTION 2. ADAPTATION, PLANNING, AND RESILIENCE FOR HEALTH

These indicators are aimed at evaluating and monitoring actions and measures to enhance or improve adaptation and resilience to climate change. For Italy, two indicators were defined and are reported below.

City-level climate change risk assessments

This indicator, taken from the 2022 global *Lancet* Countdown report (indicator 2.1.3),[12] uses data from the 2021 survey of global cities of the CDP (formerly known as the Carbon Disclosure Project) to capture the number of Italian cities that reported having completed a climate change risk or vulnerability assessment; and the climate-related health impacts and vulnerabilities that cities identified. The survey from the CDP offers a standardised reporting system, where cities across the World disclose their progress towards climate change adaptation and mitigation efforts in a format that allows for comparison between cities, and across time.

Urban green space
This indicator uses data from the 2022 *Lancet* Countdown report (indicator 2.3.3)[12] to provide an estimate of the amount of greenspace coverage in urban centres with over 500,000 inhabitants, using the satellite-based Normalized Difference Vegetation Index (NDVI) categorised in very low if <0.3, low between 0.30 and 0.39, moderate between 0.40 and 0.49, high between 0.50 and 0.59, and very high if >0.60. To assess human exposure to greenspace, as well as its urban distribution, the urban NDVI level is presented as a population-weighted average at a spatial resolution of 1 km x 1 km. Because of the population size restriction (over 500,000 inhabitants) of this indicator, only six Italian cities were considered in the analysis: Genoa, Milan, Naples, Palermo, Rome and Turin.

SECTION 3. MITIGATION ACTIONS AND HEALTH CO-BENEFITS
These indicators aim at monitor and evaluate climate change mitigation actions that reduce greenhouse gas (GHG) emissions and have benefits for local populations' health. For Italy, five indicators were defined and are reported below.

Energy system and health
This indicator uses data from the 2022 *Lancet* Countdown report (indicator 3.1)[12] and from the International Energy Agency (IEA) and tracks three components:
1. the carbon intensity of the energy system which represents the tonnes of CO_2 emitted for each unit (in TJ) of primary energy supplied in Italy;
2. the total and share of electricity generation from coal (% of total generation from coal) and global generation from coal (in TWh);
3. the total renewable generation (including solar, wind, geothermal, tidal and wave energy), in TWh, and as a % share of total electricity generated.

Transport mode
This indicator expands on the approach of the 2022 global *Lancet* Countdown (indicator 3.4),[12] using fuel-use data (by fuel type) from the IEA and from the Italian Ministry of Transport divided by corresponding population statistics to monitor fuels used for road transport and electric vehicles.[16-18] Data is used to monitor the annual change in distance travelled by passenger using car, public transport or for the transport of goods by roads using data from the ministry of transport.

Emissions from agricultural consumption
This indicator, using data from the 2022 global *Lancet* Countdown report (indicator 3.5.1),[12] tracks emissions from agricultural consumption of food products, modelling the emissions from each commodity and taking into account data on the consumption of agricultural products, and their trade balances from the Food and Agriculture Organization of the United Nations (FAO). The full methodology is described in the *Lancet* Countdown 2022 report. In brief, the indicator builds on the work of Dalin et al.,[19] adapting the model used for tracing water consumption to calculate the GHG footprint associated with the consumption of agricultural products. For this purpose, consumption is defined as the sum of local production and imports, with exports subtracted. GHG emission intensity values associated with the production of a given commodity are used to convert the mass consumed of primary commodities (in tonnes) into carbon dioxide equivalents (CO_2e). The emission associated with the consumption of secondary commodities is calculated using conversion factors from primary commodity intensities, as derived in Dalin et al.[19] The trade balances take into

account that a given commodity may have been produced in one country, processed in another and finally imported into a third.

Diet and health co-benefits
Using data from the 2022 global *Lancet* Countdown report (indicator 3.5.2),[12] this indicator models the deaths attributable to red meat consumption by linking food consumption estimates from the FAO with previously-published dietary relative risk parameters.

Healthcare sector emissions
Using data from the 2022 global *Lancet* Countdown report (indicator 3.6),[12] this indicator tracks both direct and indirect emissions from the global healthcare sector using environmentally extended multi-region input-output (EE MRIO) models, combined with annual data on healthy life expectancy at birth.

SECTION 4. ECONOMICS AND FINANCE
These indicators focus on the economic and financial costs and impacts of climate change and its mitigation. For Italy, only one indicator was defined and is reported below.

Net value of fossil fuel subsidies and carbon prices
Using data from the 2022 global *Lancet* Countdown report (indicator 4.2.4),[12] this indicator takes into account all carbon pricing instruments and fossil fuel subsidies from the World Bank Carbon Pricing Dashboard, and calculates the annual "net" economy-wide average carbon prices and revenues from the consumption of fossil fuels in the country.

SECTION 5. PUBLIC AND POLITICAL ENGAGEMENT
These indicators relate to the engagement (governance, corporate or scientific) and media coverage of health and climate change. For Italy, only one indicator was defined and is described below.

Coverage of health and climate change in scientific journals
Using data from the 2022 global *Lancet* Countdown report (indicator 5.3),[12] this indicator is based on searches in in the Web of Science, Scopus or MEDLINE, using a machine-learning-assisted methodology (topic modelling and geoparsing) to map scientific articles on health and climate according to article titles, keywords, and abstracts, as detailed in the Supplementary Material of the 2022 global *Lancet* Countdown report.[12] The search was restricted to papers first-authored by researchers affiliated to an Italian institution.

RESULTS AND DISCUSSION
SECTION 1. CLIMATE CHANGE IMPACTS, EXPOSURE, AND VULNERABILITY
The rapidly changing climatic conditions are leading to an increased frequency and intensity of extreme weather events that threaten the health of the Italian population both directly and indirectly. In parallel, Italy has a high percentage of vulnerable population subgroups, including the elderly, people with chronic disease, outdoor workers, and migrant groups, which will be more frequently affected by these effects. Climate change, therefore, is threatening to exacerbate health inequities among the Italian population. This section tracks the changing exposure of the Italian population to climate-related hazards, including extremes of heat, drought events, and climate-sensitive infectious diseases.

Exposure of vulnerable populations to heatwaves

Results show a steady increase in the person-days of exposure to heatwaves of over-65-year adults in Italy, with an average of 109.5 million more person-days of exposure (defined as one person exposed to one day of heatwave) per year in 2012-2021, than in the 1986-2005 baseline period (Figure 1). For children under one year of age, there were an estimated average of 3.9 million additional person-days of heatwave exposure affecting this vulnerable group per year in 2012-2021, compared with baseline years (Figure 1).

These increases reflect the increased frequency of days of heatwaves in Italy and represent the most direct effect of a climate-change-related warming on human health. Rising global temperatures are driving an increase in the frequency, intensity, and duration of extremes of heat, which directly impact people's health through the exacerbation of pre-existing medical conditions (such as cardiovascular and respiratory diseases), acute kidney damage, mental health, and behavioural disorders, adverse mental health outcomes, and increased risk of violence.[20,21] Additional work should be done to develop specific indicators on the health effects and capture other heat-related vulnerabilities at the local level. The elderly and newborns are not the only ones susceptible to the health risks of high temperatures and heatwaves. Pregnant women, socially-deprived people, and those working outdoors or in non-cooled environments have also been identified as being susceptible to heat-related health effects.[12,22]

Drought

The Italian land surface area affected by drought conditions increased since the 50s, with rapid increases in the land area affected by exceptional drought observed particularly since the start of the 2000s (Figure 2). On average, in the period 2017-2021, an additional 25% of the Italian land area experienced at least one month of extreme drought than in 1950-1954, and an additional 19.2% experienced at least one month of exceptional drought (Figure 2).

Climate change is driving an increase in the frequency, intensity, and duration of drought events. This poses threats to water security, sanitation and food productivity, and increases the risk of wildfires and exposure to pollutants.[23,24] Italy, the second European country (after Greece) for freshwater abstraction for public water supply, with 153 m^3 of water extracted per inhabitant in 2018,[25] is particularly at risk. Summer 2022 has also been a critical year in terms of drought and water scarcity, with 5 regions in Italy being granted the state of emergency and thus adopting appropriate measures to respond to water shortages during the summer months. Similarly, in 2020, water scarcity forced 11 Italian cities to implement water rationing measures[26] and most recently in summer 2022 the state of emergency related to drought and water shortages was declared in 6 regions.[27] More frequent and extreme weather conditions, coupled with the aging of drinking and wastewater infrastructures (60% of Italian infrastructures were more than 30 years old in 2016),[28] could lead to declining quantity and quality of water in the future years, putting sanitation and food and water security at risk in the Country.

Climate suitability for infectious disease transmission

Climate change-driven alterations in environmental conditions are resulting in changes in the environmental suitability for the transmission arthropod-, food-, and water-borne diseases.[29,30] Worldwide cases of Dengue, transmitted mainly by *Aedes aegypti* and *Aedes albopictus* mosquitoes, have doubled every decade since 1990, and climate change has been identified as one of the major drivers of this increase.[31,32]

In 2012-2021 in Italy, modelled data for Dengue transmitted by *Aedes albopictus* mosquitoes revealed a still relatively low R_0 (0.26 on average). However, this represents a 73% increase from the 1951-1960 baseline, in which the R_0 was 0.15. In this period, the biggest increase in the estimated R_0 is observed in the North of Italy, particularly in Friuli Venezia Giulia, Veneto, Lombardy, and Liguria Regions (Figure 3).
In agreement with these modelled data, in 2020 the first outbreak of autochthonous Dengue in Italy was reported in Veneto Region.[33] Further, with similar environmental niches, the R_0 for Zika and Chikungunya diseases are expected to follow similar trends. In fact, two outbreaks of Chikungunya disease were detected in Italy in 2007 and in 2017.[34,35] As the climate continues to change, this emerging risk will become more prominent. Therefore, Italy must build the adaptive capacity to cope with these hazards in the short and longer term. In this regard, in 2020, a National plan against arbovirus infections defined the measures to be implemented to set up effective preparedness and control strategies.[36]

Discussion

This section provides evidence that climate changes are already putting the health of Italian populations at risk. Climate change is already affecting the health of Italian populations, with a yearly average of almost 110 million more person-days of heatwave exposure in people over 65 years of age in 2010-2020 compared to 1986-2005. In 2017-2021, an additional 25% the land surface was affected by at least one health month of drought than in 1950-1954, putting food and water security at risk. Finally, the changes in climatic conditions are also affecting the environmental suitability for infectious disease transmission, with the predicted R_0 of dengue transmitted by *Aedes Albopictus* mosquitoes having increased by 73% in 2012-2021 with respect to the 1951-1960 baseline.
The impact of the climate changes on health is increasing over time as demonstrated by the fact that three indicators show worsening trends over the last decades. Beyond this, the findings of the 2022 *Lancet* Countdown report expose worsening trends in other health impacts and exposures at a global scale, including reduced labour potential, other extreme events like wildfires, reductions in crop growth duration, and rising of the seas level.[37] These findings highlight the need of stronger adaptation and mitigation measures to protect health tailored at the regional level and with strong national coordination, to enhance resilience and adaptive capacity of local populations to climate change. Moreover, indicators should also be developed at sub-national or regional level to better characterize exposures and vulnerabilities to climate change hazards across Italy and help introduce appropriate and efficient adaptation and mitigation measures and policies that maximise benefits for health and population wellbeing.

SECTION 2: ADAPTATION, PLANNING, AND RESILIENCE FOR HEALTH

The section shows the progress on climate change adaptation in Italy, monitoring the development of national and city-level risk assessment and adaptation planning, the use of climate information services for health, and the urban green space coverage. As mentioned in the previous section, the changing climate can affect health via multiple interacting pathways, and particularly enhance the burden in vulnerable populations. The COVID-19 pandemic has offered a glimpse of the catastrophic effects that acute health shocks can have on the Italian health system. With the effects of climate change on the rise, it is of outmost importance that risks are identified and urgent action taken to protect Italian population from the health impacts of a warming world. This requires building resilience into health and health-related systems (including sanitation, food systems, and essential infrastructure), identifying vulnerable populations, implementing early warning systems to protect health, improving knowledge, monitoring health impacts, and building preparedness and response capacity, including an adequate level of resources and funding. It is important to build on the *Lancet* Countdown indicators and develop more local and sub-national tailored indicators to assess progress in adaptation to climate change in Italy.

City-level climate change risk assessments

In 2020, 22 urban centres in Italy disclosed the status of their climate change risk assessment plans to the CDP (Figure 4), a reduction of 5 cities compared to 2019.[38] Only two of these reporting cities (9%) were located in Southern Regions of Italy, with Naples reporting it has "completed the assessment" and Cosenza reported "the assessment is in progress". Of the other 20 reporting cities, 14 (64%) had already completed a climate change risk assessment, three were in the process of undertaking one (14%), two planned to conduct an assessment within the next two years (9%), and one reported not knowing the status of the assessment (4%).

Similar trends regarding North-South divide were observed in responses to CDP survey questions on health risks associated with climate change.[38] Of the 17 cities, 10 identified their city faced risks to public health or health systems associated with climate change. The greatest climate-related health issues identified by these cities were heat-related illness (13 out of 17 cities), exacerbation of non-communicable diseases (respiratory and cardiovascular symptoms (12 out of 17 cities), and direct physical injuries and deaths due to extreme weather events (5 out of 17 cities). The most vulnerable populations affected by these climate-related impacts were identified as elderly (12 out of 17 cities), children and youth (7 out of 17 cities), marginalised or minority communities (4 out of 17 cities), and outdoor workers (4 out of 17 cities).

By 2020, 35.3% of Italian population was living in cities[39] , findings from this indicator highlight disparities in assessments of climate health risks across Italy, with the Southern cities scoring worst, which may hamper the North-South inequities. However, we acknowledge that this indicator relies on the CPD survey, which was completed in Italy by only a small selection of cities as described above. Since CDP reporting is voluntary, many cities that could have developed risk assessments might not be represented in this survey, and, as such, these results might provide a partial and incomplete picture of the current situation.

Urban green space

Averaged across the six Italian urban centres sampled, the population-weighted peak NDVI in Italian cities increased by 12% from 2010 to 2021 (population-weighted mean NDVI 0.32 to 0.36). This varied between an 8% increase in Rome and a 27% increase in Milan (Figure 5). Milan was the only Italian urban centre classified as moderately green or above in 2021 (population-weighted peak NDVI of 0.41). However, despite this progress, the overall average level of green space in the mentioned Italian urban centres remained low in 2021 (population-weighted mean NDVI 0.36). Moreover, data exposed persisting inequalities in the availability of green space between cities in Northern and Southern Regions of Italy, with Naples and Palermo recording the lowest population-weighted peak NDVI in both 2010 (population-weighted peak NDVI of 0.29 and 0.28, respectively) and 2021 (population-weighted peak NDVI of 0.32 and 0.33, respectively).

These results reinforce the importance of local decision-makers across Italy increasing access to urban green spaces that are safe and enjoyed by everyone. With their potential to simultaneously improve health outcomes, reduce health inequities, and facilitate climate mitigation and adaptation, urban green space design must involve interdisciplinary experts to ensure that health and environmental benefits are maximised.[40]

Discussion

With the impacts of climate change continuing to rise, risk assessment and implementation of adaptation interventions is urgently needed to protect the health of Italian population. Despite clear evidence on the growing health risks, the implementation of adaptation measures to protect the health of Italian populations from climate change hazards has been slow. Engagement with international standards on climate change adaptation and risk assessment has also been slow: in 2021, only 21 urban centres in Italy reported the status of their climate change risk assessment plans to the CDP. Differences in the rollout and availability of adaptation measures in different regions, such as those observed in the availability of urban green spaces between Northern and Southern cities, clearly demonstrate that health inequities can be accentuated without central guidance. Considering that in August 2022 Italy had still not approved its National Adaptation Plan, submitted to public consultation in 2017, mechanisms must be put in place to track the implementation of further adaptation and maladaptation measures (including the use and availability of cooling systems, the implementation of climate-resilient infrastructure, and the implementation of early warning systems, among others), that, under a central guidance, could monitor progress and develop evidence-based policies to protect the health of Italian population in the face of the changing climate.

SECTION 3. MITIGATION ACTIONS AND HEALTH CO-BENEFITS

In Italy, greenhouse gas emissions reduced from 519 to 418 CO_2 equivalent million tons ($MtCO_2$ eq) between 1990 and 2019, for a total decrease of 19.5%.[41] Despite this moderate progress, Italy should decrease greenhouse gas emissions by 17 $MtCO_2$ eq per year from 2020 to reach the EU target of a 55% reduction by 2030, followed by a cut of 12 $MtCO_2$eq per year over the subsequent 20 years to reach net zero emissions by 2050. Concerningly, Italy is not on track to meet this ambition, particularly since the decrease in greenhouse gas emissions has flattened in the last 5 years, with a mean cut of only 1 $MtCO_2$eq per year between 2015 and 2019.[41] Restrictions linked to the COVID-19 pandemic offered an opportunity to accelerate the reduction of greenhouse gas emissions, with an estimated 9% decrease in 2020 compared to 2019.[42] However, this decrease was transient and is likely not to contribute significantly to emissions reductions in the long term. Moreover, the implementation of the measures described in the Italian national energy and climate plan (NECP) would fail in achieving net zero emissions, with an estimated residual of 220 $MtCO_2$ eq in 2050, requiring further efforts.[43]

Accelerated action towards decarbonisation can not only prevent the most extreme impacts of climate change, but also deliver substantial and immediate health co-benefits through cleaner air, healthier lifestyles, and better diets. This section tracks Italy's efforts toward ensuring a reduction in greenhouse gas emissions and delivering the associated health co-benefits. Indicators track progress towards the decarbonisation of the energy system, progress towards reducing greenhouse emissions from the health system, shift to sustainable transportation modes, emissions from agricultural products and the associated health impact of red meat consumption, and progress towards reducing greenhouse emissions from the health system.

Energy system and health

Fossil fuel combustion within the energy system is the largest single source of greenhouse gas emissions, with a global share of 65% of all emissions.[44] A rapid shift to renewable energy use is crucial not only to mitigate these emissions, but also to prevent deaths due to ambient air pollution from fossil fuel burning.
The indicator tracks the carbon intensity of the energy system in Italy has been declining slowly, reaching in 2019 its lowest value since at least 1970, with a reduction of 25% since that year. However, at the pace of decarbonisation observed since 2015 (the year the Paris Agreement was signed), it would take Italy 79 more years to fully decarbonise its energy system, given the carbon intensity of 48.5 tCO2/TJ registered in 2020 (with a mean ~0.61 tCO_2/TJ reduction per year over the 6-year period 2015-2020). In recent years, Italy has made good progress in reducing its coal consumption: while 16% (45.4 TWh out of the total 281.6 TWh) of its electricity was produced from coal in 2015, this figure reduced to 6% in 2019 (17.9 TWh out of the total 290.0 TWh) (Figure 6). Nevertheless, despite this progress, with coal burning resulting in the emission of dangerously high levels of health-harming air pollution, much is yet to be done to decarbonise Italy's energy system while protecting the health of its population. Concerningly, most of the reduction in electricity generation from coal between 2015 and 2019 has been met with an increase in the electricity generated from natural gas, which made up 49% (143.2 TWh out of 290.0 TWh) of all the electricity produced in Italy in 2019 – 10 percentual points more than in 2015, when it contributed to 39% (110.9 TWh out of 281.6 GWh) of the electricity produced (Figure 6).
The Italian integrated National Energy and Climate Plan (NECP) set to 55% of the total electricity generation its target for renewables by 2030.[45] However, after some fast progress in shifts to renewable sources for electricity generation in the early 2010s, the transition toward electricity generation from new renewables (solar photovoltaics and thermal, wind, geothermal, tide, wave and ocean energy) in Italy has stalled in recent years, and only 17% (50.7 TWh of 290.0 TWh) of the total electricity produced in 2019 came from these sources – just one percentual point more than in 2015, when it represented 16% of all the electricity produced (44.6 TWh of 281.6 TWh) (Figure 6). In parallel, from 2015 to 2019, the electricity generated from other renewable sources that have a higher environmental footprint, such as hydropower, biofuels and waste, has not increased either: 7% of all the electricity generated in 2019 (21.6 TWh out of 290.0 TWh) came from biofuels and waste, one percentual point less than in 2015 (8%) (21.8 TWh of 281.6 TWh). Meanwhile, hydro energy represented 16% of all electricity generated both in 2015 and in 2019 (45.4 TWh of the total 281.6 TWh and 17.9 TWh of of the total 290.0 TWh, respectively). Under current trends, Italy is not on track to meet the planned decarbonisation targets unless immediate action is taken to accelerate decarbonization. Recent policy frameworks and funding for COVID-19 recovery, both at EU level through Next Generation EU and nationally via The Italian Recovery and Resilience Plan (*Piano nazionale di ripresa e resilienza*, PNRR), can help boost the green transition and reach decarbonization goals enhancing benefits for the local population.[46]

Transport mode
Following the COVID-19 pandemic, global use of public transport fell by 50% to 90% and rail by 80%.[47] The pandemic triggered the promotion of walking and cycling (active travel), which could not only cut emissions, but also provide enormous health dividends through the increase of physical activity and the reduction of air pollution.[9] The carbon intensity of road transport has remained stable in Italy since 1990.[48] While the energy used for road travel has been on a downward trend in Italy since 2006, this is most likely a reflection of the reduced use of road travel for the transport of goods, which had decreased by 45% in 2018 with

respect to the 2005 level (Figure 7). Car traffic, on the contrary, was 38% higher in 2018 than in 1990, and still represented 87% of all passenger road travel (Figure 7).
Italy's long-term strategy to achieve net zero emissions includes shifting toward renewables and electromobility with the goal of reaching 19 millions of battery electric vehicles (BEVs), equal to 80% of the total vehicle fleet, and 4 million of hydrogen cars, equal to 17%, by 2050.[43] However, the use of electric vehicles remains very limited in the Country, electric cars representing less than 5% of the newly registered vehicles in 2021 (67,263 out of total 1,457,971 new vehicles).[49] Fossil fuels still largely dominate road travel, accounting to 96% of all the energy used in 2019.
Shifting away from fossil fuel use in road travel would not only lead to reduced CO_2 emissions and reduced air pollution in urban centres, but would also lead to health gains from more active lifestyles if active forms of travel are promoted.

Emissions from agricultural consumption

Food systems, including agricultural production, are responsible for 21-37% of all greenhouse gas emissions, while also holding high carbon sequestration potential.[50] This makes them the key to limiting global warming to 1.5° C.
Data from this indicator shows that per-capita greenhouse gas emissions resulting from the consumption of agricultural goods had fallen by 28% by 2019 with respect to the year 1995 in Italy (Figure 8). This was driven primarily by a 39% reduction in the emissions related to cattle meat and dairy products consumption. However, emissions from the consumption of animal products still contributed to 79% of all agricultural consumption-based emissions in 2018. The consumption of products derived from cattle was the main contributor, accounting for 59% of all emissions from the consumption of agricultural products that year – with the consumption of cattle red meat accounting for 40% of all agricultural consumption-based emissions (Figure 8).
With current production efficiency interventions failing to curb or reduce agricultural greenhouse gas emissions, dietary shifts – greatly reducing red meat and increasing plant-based foods – are necessary and would save thousands of lives per year from reduced red meat consumption.[9]

Diet and health co-benefits

As the previous indicator shows, the consumption of animal-derived foods, particularly red meats, are a leading source of agricultural emissions in Italy. Importantly, their excessive consumption is also associated with adverse health outcomes, particularly in relation to red meat. This indicator estimated that, in 2019, an estimated 24,120 deaths, representing 21% of all deaths attributable to dietary risk factors, were attributable to excess red meat consumption (including processed meat) in Italy – down by less than 1% from the previous year. Concerningly, this makes Italy the third country with the highest number of deaths attributable to excess red meat consumption in the European union, after Germany with 50,240.
A previous study conducted in Italy evaluated the health co-benefits and decrease in greenhouse gas emissions by changing dietary habits and reducing meat consumption.[51] Considering different meat reduction scenarios, around 4% of colorectal cancer and cardiovascular deaths would be avoided with some geographic heterogeneity, while a reduction in emissions due to dietary changes would be in the range of 8,000-14,000 GHG CO_2e per year.[51] Reducing red meat consumption in Italy, therefore, offers the opportunity to

simultaneously curb agricultural greenhouse gas emissions and improve the health of Italian population.

Healthcare sector emissions

Italy is amongst the countries with the highest healthcare quality, as measured by the Healthcare Access and Quality Index (HAQ) and its healthy life expectancy – and it is also one of the countries with the lowest emissions in the healthcare sector as compared to other countries with similar levels of healthy life expectancy (Figure 9). This reflects the efficacy of resources used in the healthcare sector.

However, the Italian health system has not made significant progress in reducing its emissions and, on a per capita basis, these have remained fairly stable since 2005 and contributed in 2019 to 458 $kgCO_2e$ emitted per inhabitant.

In acknowledging the health impacts of climate change, the health sector must lead the decarbonisation efforts if it is to deliver healthcare without doing harm.

Discussion

Italy's mitigation response has been partial compared to what is needed to meet commitments under the Paris Agreement and the delay may come at major costs to human health. Although Italy has made some progress on reducing its greenhouse gas emissions since 1990, all the five indicators presented in this section show that the pace of reduction is insufficient to meet the current commitments and would contribute to a world of catastrophic levels of warming in the next decades. Indeed, Italy was still sourcing 6% of its electricity from coal in 2019, and fossil fuels still accounted for 96% of all the energy used for road travel in 2017. At the average annual decarbonisation rate observed between 2015-2020, it would take Italy several decades to fully decarbonise its energy system. Further, estimates from the *Lancet* Countdown suggest that, in 2019, greenhouse gas emissions related to the consumption of animal products represented 79% of all emissions from the agricultural products consumed in Italy. According to the *Lancet* Countdown modelling, the associated excessive red meat consumption would have contributed to more than 24,120 premature deaths, making Italy the second country with the highest total number of deaths attributable to excess red meat consumption in Europe, after Germany. Accelerated decarbonisation, therefore, offers both the possibility of delivering a sustainable, safer future and immediate health benefits to Italian populations through cleaner air, more physical activity, and healthier, low-carbon diets.

SECTION 4. ECONOMICS AND FINANCE

Climate changes impact health directly through exposure to climate hazards, as well as indirectly by affecting social and economic systems, thus undermining the social determinants of good health.[52] The economic costs of climate change are diverse and include, among others, loss of labour due to heat exposure, disease, loss of capital and infrastructure, or climatological disruption; the disruption and loss of physical assets caused by climate change-related extreme events; and the costs to the health system of the direct human impacts of climate change.[20]

In parallel, the transition to a low-carbon, healthy future requires the rapid transition of economic and financial systems. Despite the near-term costs of decarbonising economic systems, previous studies estimate that accelerated action to limit warming to 1.5º C by the end of the century would generate a net economic benefit in the order of trillions of US dollars.[53] For the economic transition to be possible, the full economic costs of climate change must be taken into account. This section explores one of this transition key aspects: the pricing of carbon emissions and the value of fossil fuel subsidies.

Net value of fossil fuel subsidies and carbon prices

Carbon pricing instruments can provide financial incentives that promote the transition toward a low-carbon economy and help reflect the real cost of fossil fuels burning and its negative externalities. However, few countries around the World have implemented carbon prices and, in many cases, are still devoting public funds to subsidising fossil fuels.[20] Analysis by the International Monetary Fund found that, in 2020, taking into account environmental costs and foregone consumption taxes, fossil fuels were subsidised globally for a total of US$6 trillion – equivalent to 6.8% of global GDP.[54]

Despite Italy operating under the EU Emissions Trading System (EU ETS), data from this indicator shows that it was still significantly allocating net financial subsidies to fossil fuel burning in 2019, with a net negative carbon price of 33.6 US$ (real 2020 US$) per tonne of CO_2 released into the atmosphere. Taking into account all emissions, Italy spent 10.4 billion US$. Importantly, these funds are equivalent to 5.7% of all national health spending that year, representing a similar amount that is financed each year for disease prevention in Italy. Correcting these distortions could deliver enormous benefits to human health and wellbeing, both through reducing fossil fuel burning and redirecting public funds towards public health prevention, healthcare, and health-related services.

Discussion

The continued use of public funds to subsidise health-harming fossil fuel burning is partly responsible for the slow progress toward decarbonization. In 2018, Italy dedicated the equivalent of 5.7% of its national health budget to this purpose. With the high level of taxation in Italy, redirecting public spending towards public health prevention, healthcare, and health-related services, Italy could deliver significant net benefits to its entire population. Furthermore, the transition to a low-carbon economy could see a net job generation and economic activity in the renewable energy and energy efficiency sectors and secure net economic benefits from the transition to a healthier economy.[55]

SECTION 5. PUBLIC AND POLITICAL ENGAGEMENT

Action to protect health in the face of the changing climate requires, first and foremost, the key actors in society to acknowledge and engage with the interlinkages between climate change and health. Policy-makers' engagement is paramount to driving change, especially in a democratic country like Italy; public engagement is central to driving political action. As recognised and respected experts, scientists also have a major role to play and can shape climate action by promoting understanding and generating sound evidence of the impacts of climate change and the benefits of accelerated action. This section monitors these aspects by tracking engagement in climate change and health from the scientific community and political leaders in Italy.

Coverage of health and climate change in scientific journals

Scientific evidence is a key to enabling evidence-based decision-making for health and climate change and is critical in shaping public and political engagement in these issues.[56,57] Scientific engagement on health and climate change led by researchers affiliated to an Italian institution increased almost four times in the last decade, with 12 articles in 2012 and 47 articles in 2021 (Figure 10). In 2021, Italy was the 15th country in the World with the highest

number of original research articles on health and climate change led by local researchers, a list headed by the United States (544 articles in 2021) and followed by China (532 articles in 2021).
The increased engagement of the scientific community on health and climate change is a promising trend, which will generate better evidence to tailor interventions that maximise human health. Nonetheless, the transfer of that evidence into policy will require increased collaboration between the academic and public sectors and political commitment to engage with the scientific community and respond to the evidence generated.

Discussion
This indicator provides glimpses of hope. The Italian scientific community is increasingly addressing climate change and health issues, with original research on the topic led by researchers in Italy growing from 12 articles in 2012 to 47 articles in 2021, and Italian researchers are among the World's most engaged in this field. For the evidence produced by scientists to be effectively translated into policies that protect health, increased political engagement is essential.

CONCLUSIONS
The overall picture depicted by the analysis of the 12 indicators reveals two key findings. The first finding is that climate change is already having adverse health impacts on the Italian population. Importantly, these effects are not being felt uniformly across the country or by different populations, with the most vulnerable groups being disproportionately at risk.
The second key finding is that, through accelerated action on climate change mitigation, Italy has the opportunity of delivering major and immediate health benefits to its population. The pandemic recovery funds and policies developed at European and national level through PNRR provide a unique and timely opportunity to not only boost climate action in terms of both resilience and mitigation, but also to ensure health takes a central role in all actions centring response around health benefits. Accelerated climate change mitigation through energy system decarbonisation and shifts to more sustainable modes of transport could offer major benefits to health from cleaner air and more active lifestyles. The decarbonisation of agricultural systems would similarly offer health co-benefits to Italian populations. If developed keeping people's health and livelihoods at their centre, policies to reduce GHG emissions from the agricultural and energy sectors could therefore deliver major co-benefits to health.
As respected and reliable voices, scientific leaders can foster knowledge, increase the understanding of the health dimensions of climate change, and produce evidence to help inform the development of climate policies that maximise human health and wellbeing. However, time is running out: unless urgent action is taken to tackle climate change and protect the health of the Italian population, the rapidly changing climate will have catastrophic consequences. Developing a key set of local indicators to monitor the impacts of climate change and evaluate response actions, in terms of adaptation and mitigation, can help support and enhance policy and action.

Conflicts of interests declared: none.

Acknowledgments: the Authors would like to thank the following people for their contribution to this work from the *Lancet* Countdown network: Jonathan Chambers, for the development of the *Lancet* Countdown indicator on Exposure of vulnerable populations to heatwaves; Joacim Röcklov and Sewe Maquins, for the development of the *Lancet* Countdown indicator on climate suitability for the transmission of Dengue; Patrick Kinney and Jennifer Stowell for the development of the *Lancet* Countdown indicator on urban greenspace; Harry Kennard for the provision of data for the *Lancet* Countdown indicator on Energy Systems and Health; Carole Dalin, Paula Dominguez-Salas, and Harry Kennard for the development of the *Lancet* Countdown indicator on emissions from agricultural consumption; Marco Springmann for the development of the *Lancet* Countdown indicator on Diet and Health co-benefits; Nicholas Hughes for the development of the *Lancet* Countdown indicator on the net value of fossil fuel subsidies and carbon prices; Jan Minx, Max Callaghan, Lea Berrang Ford, and Pete Lampard for the development of the indicator on the coverage of health and climate change in scientific journals.

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Figure 1. Change in the number of person-days of exposure to heatwaves of (**A**) people over 65 years of age and (**B**) children under 1 year of age with respect to the 1986-2005 baseline.
Figura 1. Differenza in anni-persona di esposizione alle ondate di calore (**A**) nella popolazione over 65 e (**B**) nei bambini al di sotto di un anno di età rispetto al periodo di riferimento 1986-2005.

LEGENDA
[puntino] annual total values
[linea] 10-year moving average

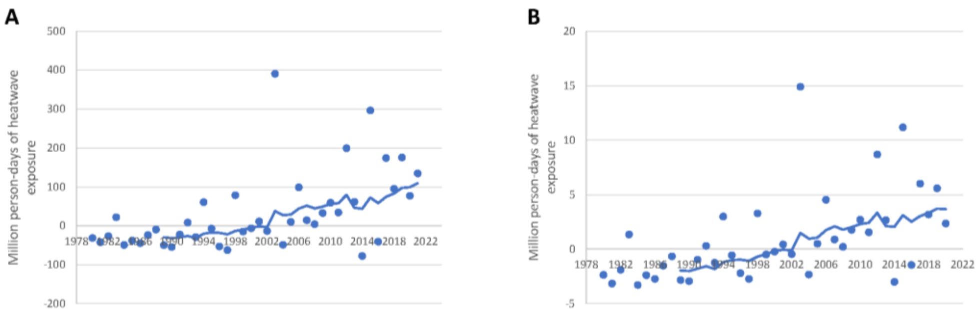
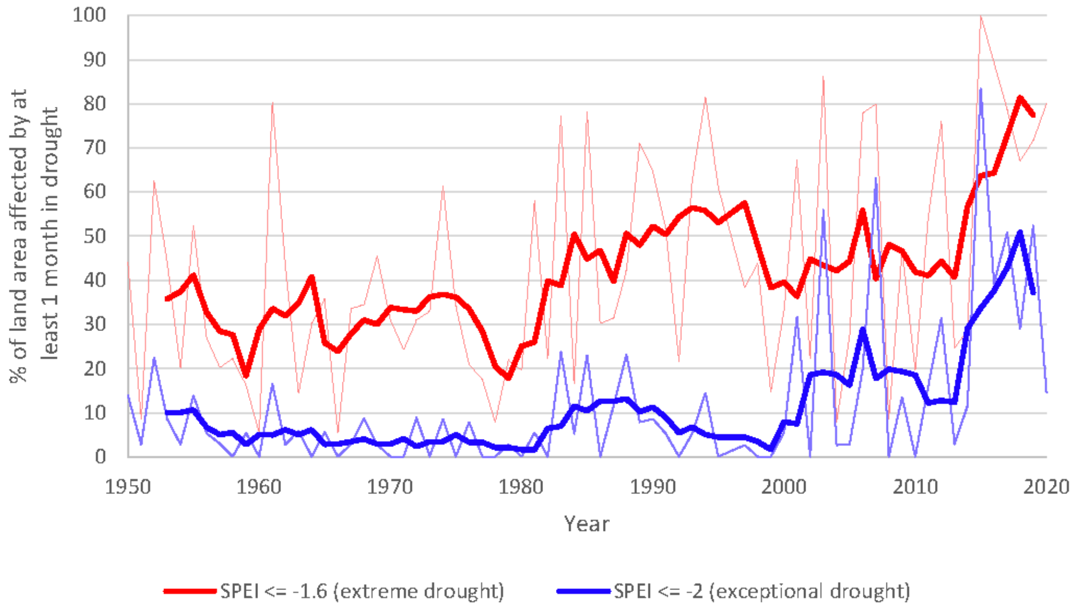

A
Million person-days of heatwave exposure
500
400
300
200
100
0
-100
-200
1978
1982
1986
1990
1994
1998
2002
2006
2010
2014
2018
2022
B
Million person-days of heatwave exposure
20
15
10
5
0
-5
1978
1982
1986
1990
1994
1998
2002
2006
2010
2014
2018
2022

Figure 2. Percentage of land area affected by at least one month of severe (red) and extreme (blue) drought.
Figura 2. Percentuale di territori colpiti da almeno un mese di siccità grave (in rosso) e estrema (in blu).



Thin lines represent the annual percentage of affected land area; thick lines represent the centred 5-year moving averages (2 years forward and 2 years backward) / *Le linee sottili rappresentano le percentuale annuali; le linee spesse rappresenano le medie mobili centrate quinquennali (2 anni prima e dopo).*

SPEI6: 6-monthly Standardised Precipitation-Evapotranspiration Index / *indice di precipitazione-evapotranspirazione standardizzato a 6 mesi*

Figure 3. Change in the basic reproduction potential (R_0) for the transmission of Dengue by *Aedus albopictus* in Italy from 1951-1960 to 2012-2021.
Figura 3. Variazione del numero di riproduzione di base (R_0) per la trasmissione della malattia dengue da *Aedus albopictus* in Italia dal 1951-1960 al 2016-2021.

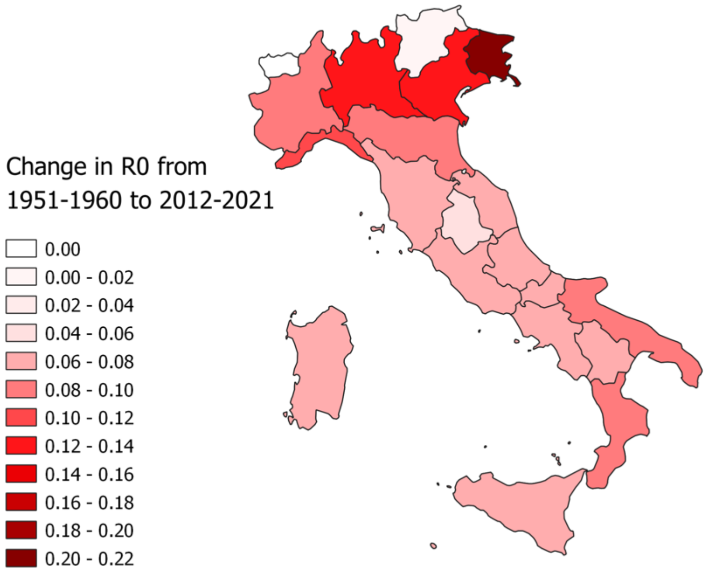
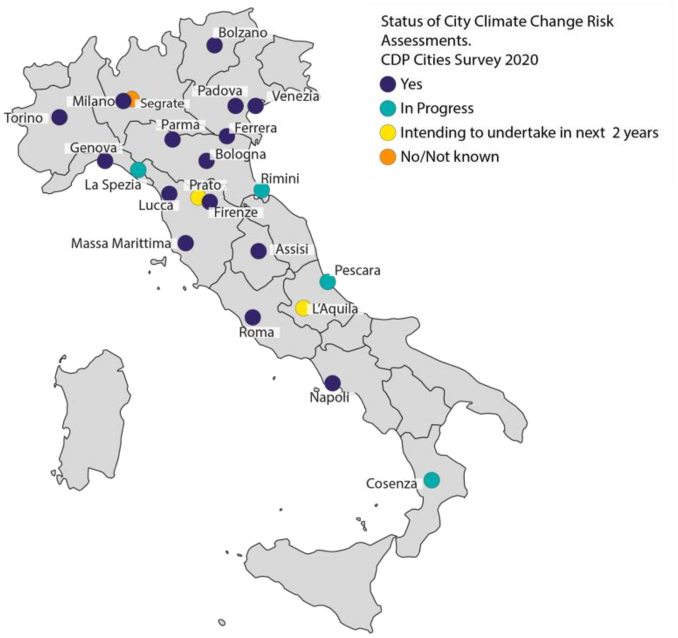


Figure 4. Status of climate change risk or vulnerability assessment and the identification of climate-related health impacts and vulnerabilities by reporting city in CDP Cities survey 2021.
Figura 4. Valutazione del rischio o della vulnerabilità ai cambiamenti climatici del rischio e identificazione degli impatti e delle vulnerabilità collegati al clima nell città che hanno partecipato allo studio CDP Cities survey 2021.



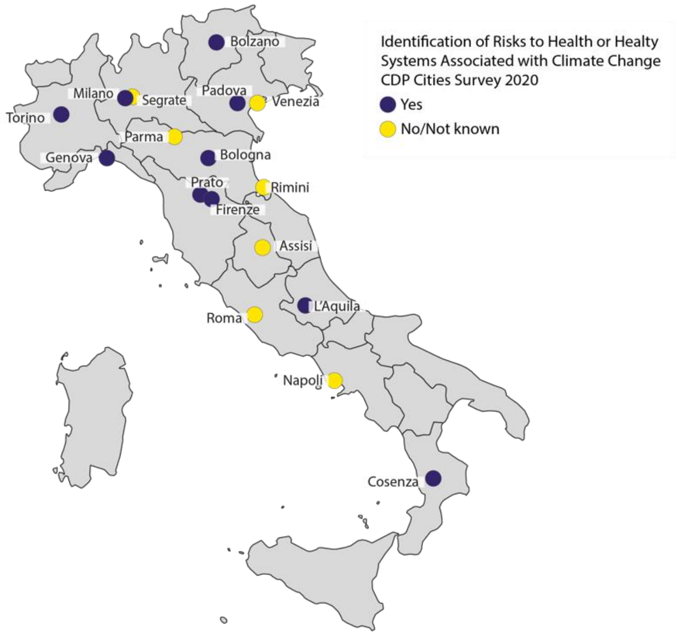


Figure 5. Level of urban greenness in Italian urban centres with over 500,000 inhabitants in 2010 and 2021.
Figura 5. Livello di verde urbano nei centri urbani italiani con oltre 500.000 abitanti nel 2010 e 2021.

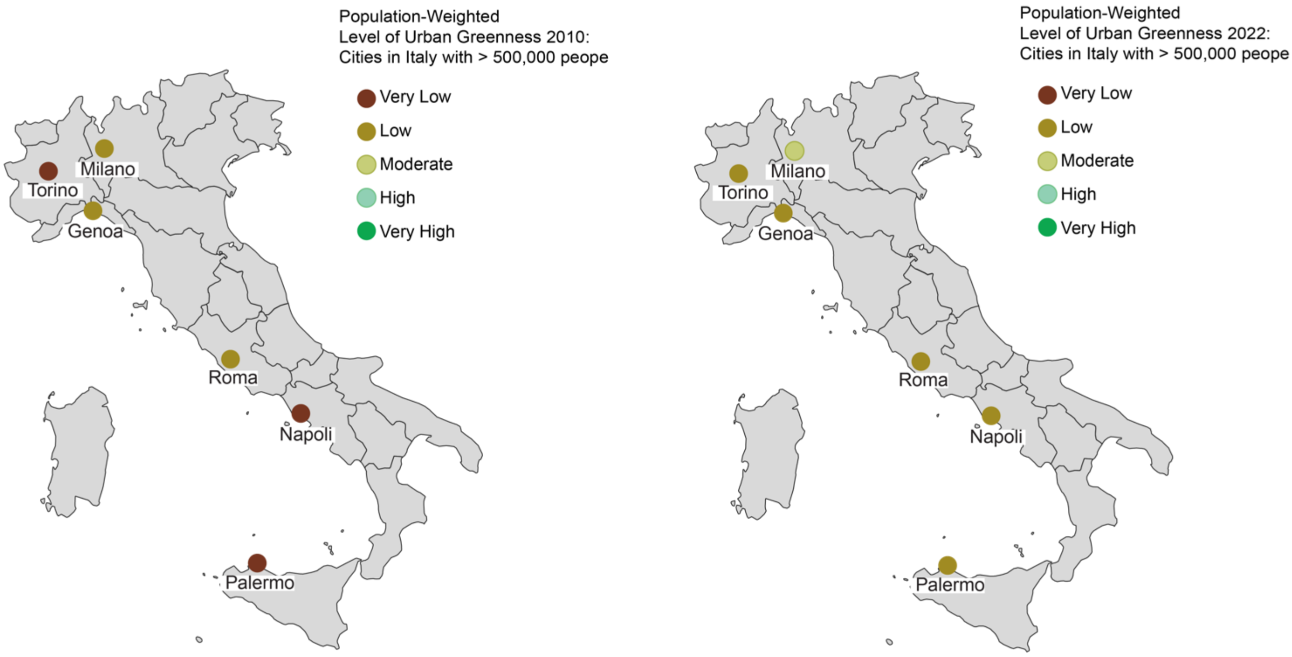


Figure 6. Electricity production in Italy by source from 2010 to 2019, presented **(A)** as percentage of total electricity produced and **(B)** as total electricity produced in terawatt-hours (TWh). Data source: International Energy Agency.
Figura 6. Fonti di produzione di elettricità in Italia dal 2010 al 2019, presentata **(A)** come percentuale e **(B)** in valore assoluto di elettricità prodotta in terawatt per ora (TWh). Fonte deo dati: International Energy Agency.

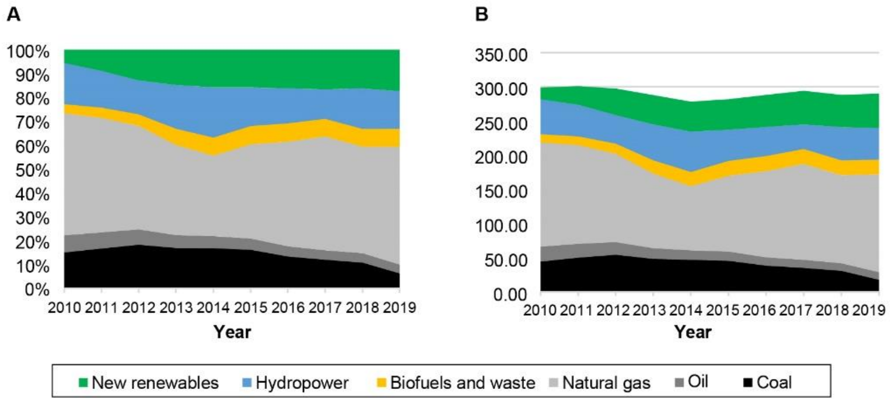
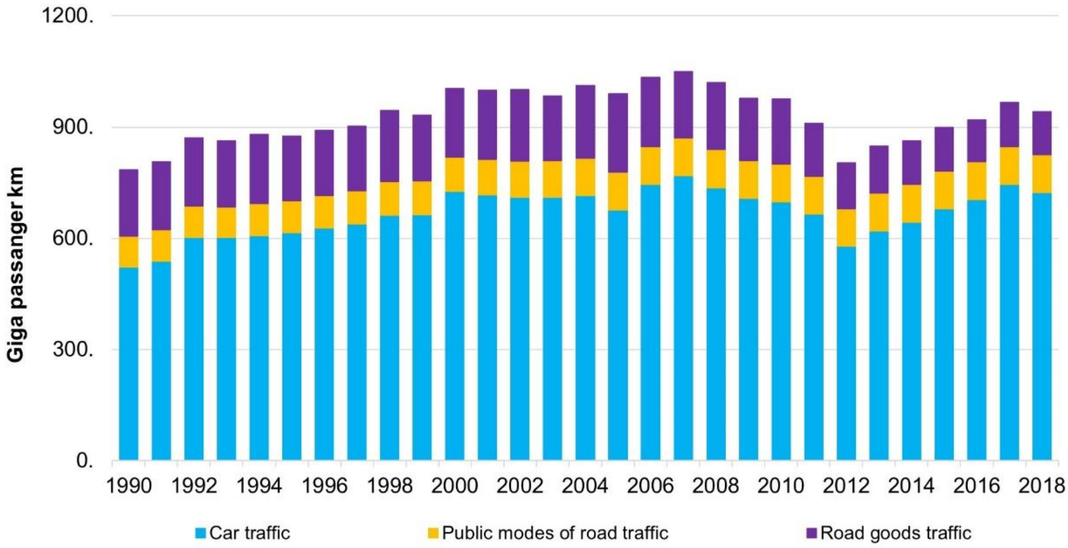
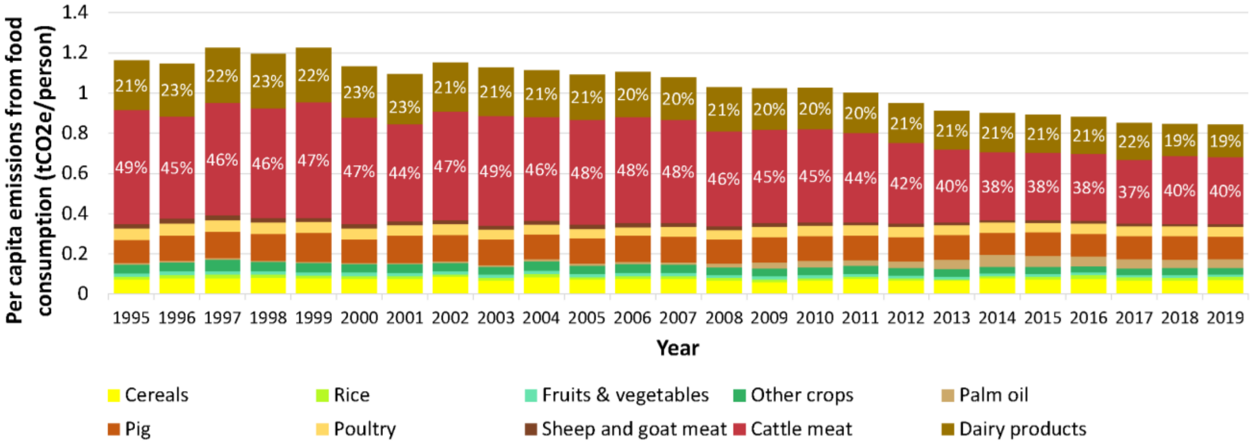

A
B
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Year
New renewables
Hydropower
Biofuels and waste
Natural gas
Oil
Coal

Figure 7. Passenger and goods road traffic in Italy.
Figura 7. Traffico su strada di passeggeri e beni in Italia.



The bar charts represent the distance travelled by passenger using car, public transport or for the transport of goods by roads using data from the Ministry of Transport.
I grafici a barre rappresentano la distanza percorsa dai passeggeri in auto, trasporto pubblico o il traffico di beni via strada usando i dati del Ministero dei trasporti.

Figure 8. Per-capita yearly greenhouse gas emissions associated with consumption of agrifood products, by commodity.
Figura 8. Emissioni annuali pro capite di gas serra associate al consumo di prodotti agroalimentari per tipologia.



Percentages represent the percentage over total greenhouse gas emissions associated with consumption of agrifood products per each year by commodity. / *Le percentuali rappresentano la percentuale sul totale delle emissioni di gas serra associate al consumo di prodotti agroalimentari per tipologia.*

Figure 9. National per-capita healthcare greenhouse gas emissions for 2019 against healthy life expectancy at birth.
Figura 9. Emissioni nazionali di gas serra da parte del settore sanitario per il 2019 rispetto alla speranza di vita alla nascita.

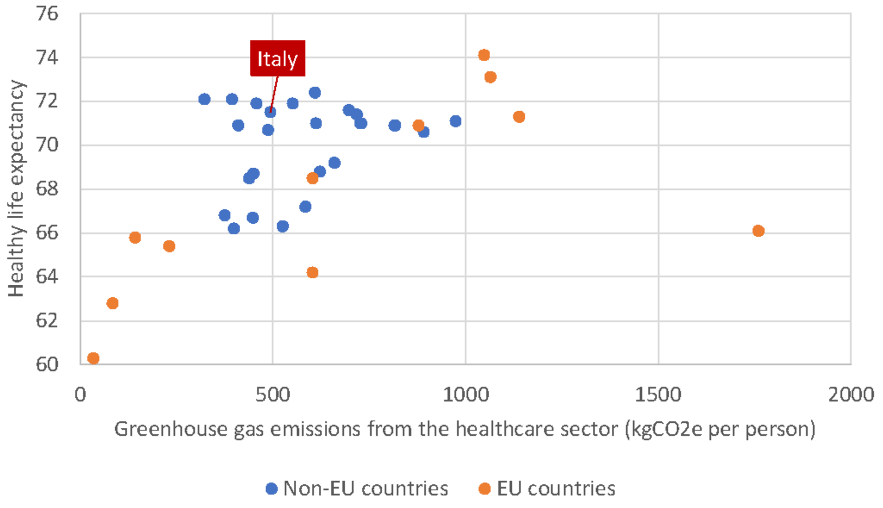


Image source: 2022 global *Lancet* Countdown Report.[20] / **Fonte dell'immagine:** Global *Lancet* Countdown report 2022.[20]

Figure 10. Scientific journal articles relating to health and climate change led by Italian researchers.
Figura 10. Articoli relativi a salute e cambiamento climatico pubblicati da ricercatori italiani come primi autori in riviste scientifiche.