Reduction of air pollution and greenhouse gas emissions due to the penetration of electric vehicles: comparative data from several countries

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Energy Forum:
Electric and Hybrid Electric Vehicles

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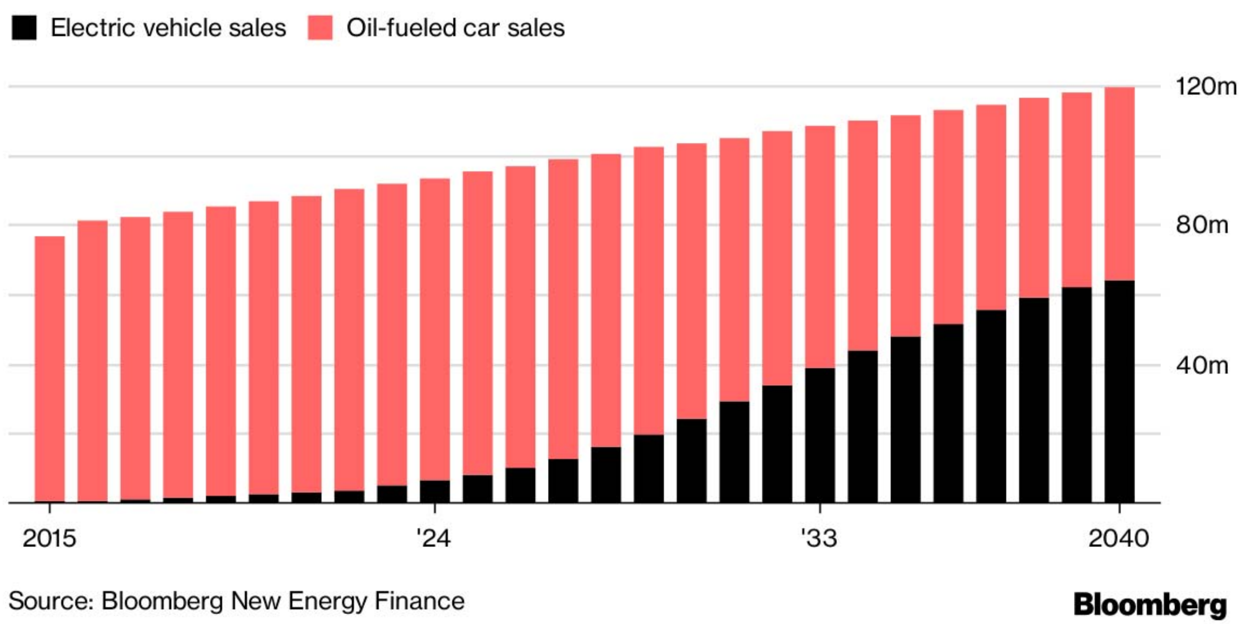
Global Electric Vehicles Sales Projections

Forecasts see the shift away from oil in transport as an incremental process guided by slow improvements in the cost and capacity of batteries and progressive tightening of emissions standards.



"Electric cars on their own may not add up to much, but when you add in car sharing, ride pooling, the numbers can get significantly greater."

David Eyton, head of technology at BP Plc

https://about.bnef.com/blog/how-electric-cars-can-create-the-biggest-disruption-since-iphone/

IEA Technology Collaboration Program

- The technology collaboration program on Hybrid and Electric Vehicles was organized to accelerate HEV and EV introduction
- Members currently includes 18 countries:
  Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal, Republic of Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States of America
- Program includes tasks on assessing technologies, business models and lifecycle impact assessment
  Task 19 – Life Cycle Assessment of EVs
- Report titled: "Hybrid and Electric Vehicles: The Electric Drive Delivers", 2015
  (http://www.ieahev.org/assets/1/7/Report2015_WEB.pdf)

LCA Conclusions

1. Environmental Assessment of EVs has been conducted based on Life Cycle Assessment compared to conventional vehicles
2. Based on about 700,000 EVs on the road worldwide (end of 2014):
   - main countries are US, JP, CN, F, DE, NO
3. Estimation of average environmental effects substituting diesel/gasoline shows:
   - GHG-reduction: - 20 %
   - PM_{10} reduction: - 60 %
   - Ozone reduction: - 30 %

LCA Conclusions (Cont'd)

4. Broad estimated ranges are mainly due to variation in:
   - **Emissions of national electricity production**
   - Electricity consumption of EVs at charging point
   - Fuel consumption of substituted conventional ICEs
   - Data availability, uncertainty and consistency, e.g., PM
5. Additional renewable electricity with adequate charging maximizes environmental benefits
6. Grid loading strategies are essential for further significant reductions

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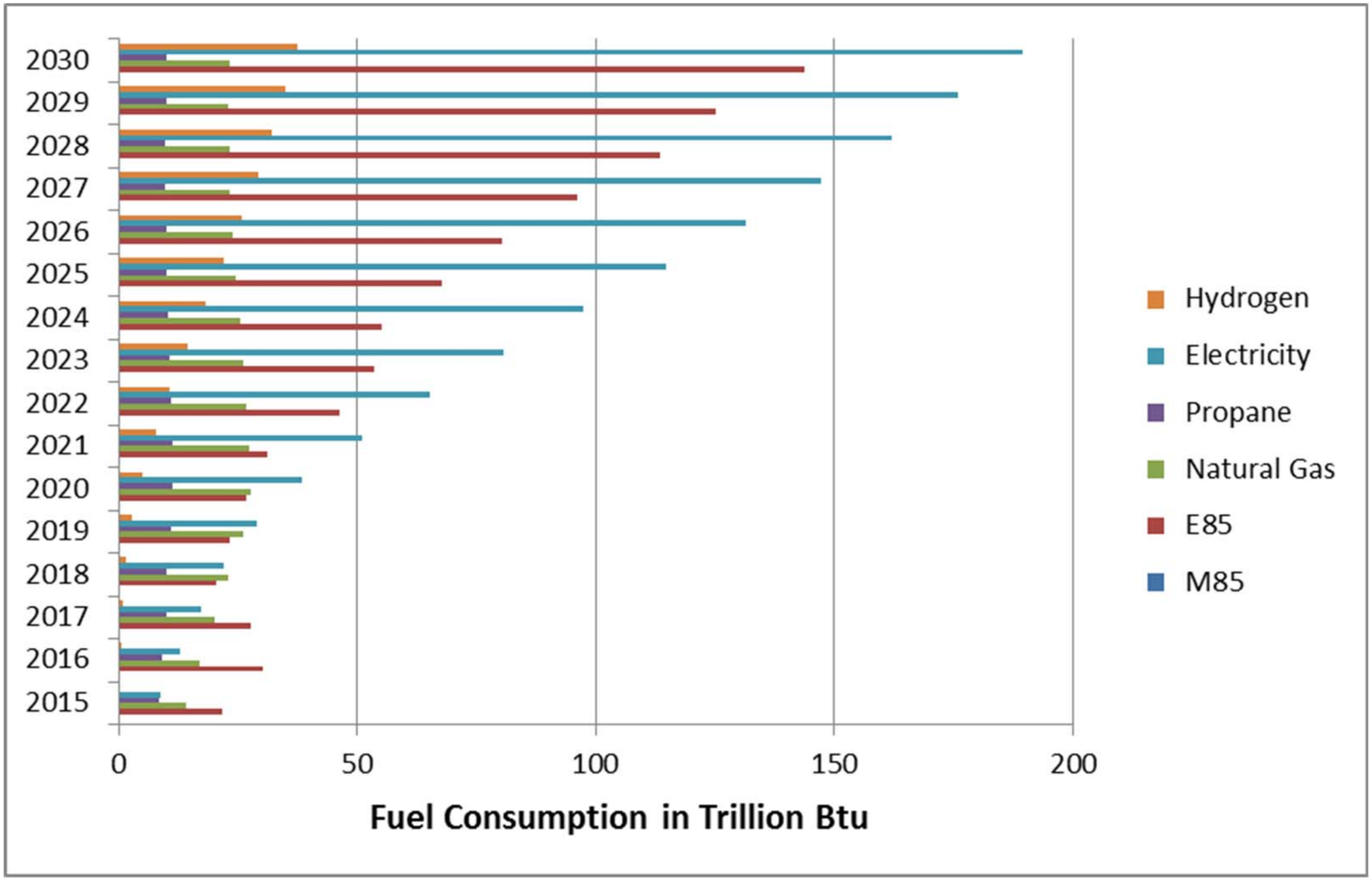
U.S. Energy Consumption Trends with Alternative Energy Vehicles

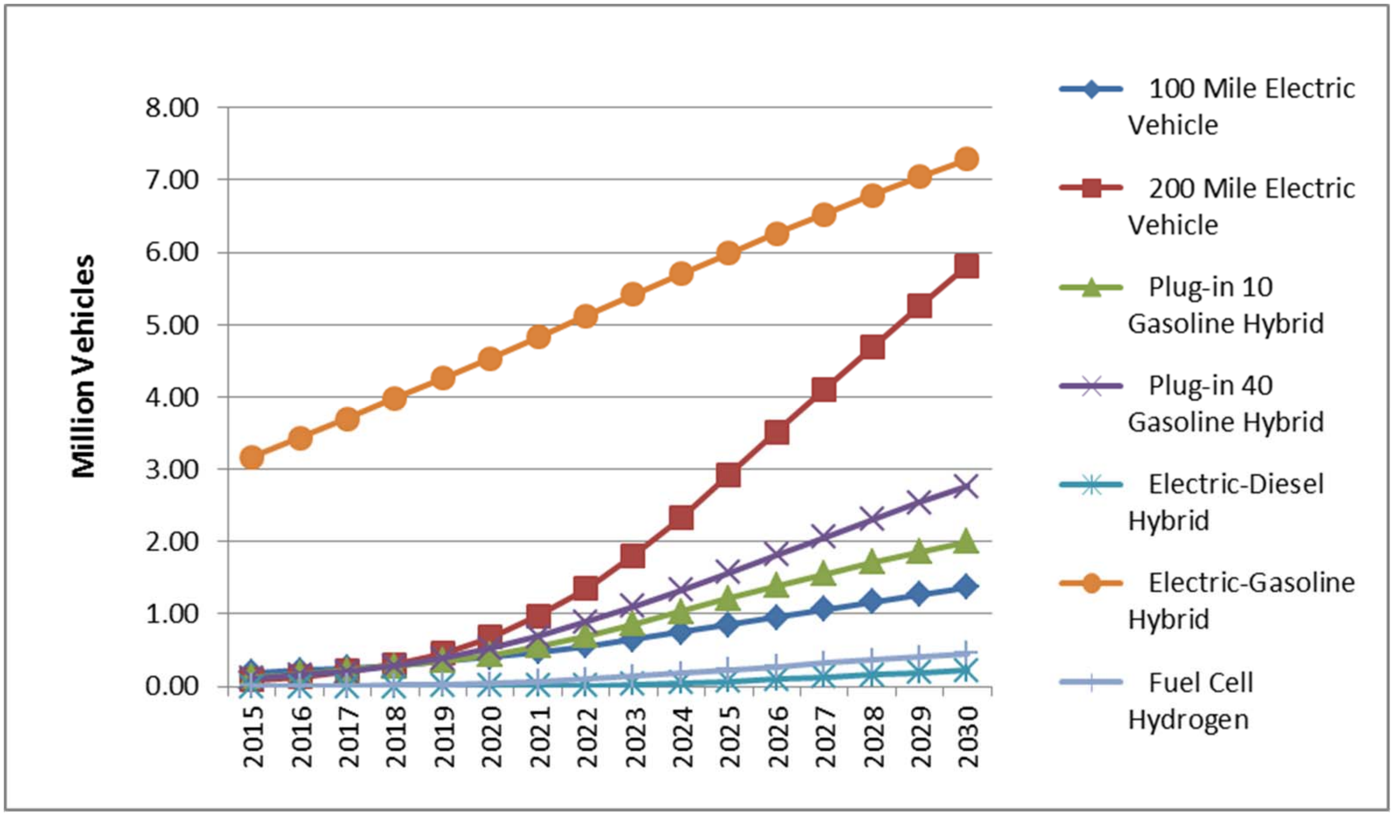
U.S. energy consumption by alternative energy vehicles is expected to increase from 11.5% in 2015 to 21.2% in 2030



Extracted from: EIA, Annual Energy Outlook 2017, Table 38

U.S. Forecast of Vehicle Technology Penetration

U.S. conventional vehicles stock is expected to decline from 113.5 million in 2015 to 95.5 Million in 2030, with expected trends for EV and HEV shown below:



Extracted from: EIA, Annual Energy Outlook 2017, Table 40

U.S. Air Quality Impact Analysis: Basic Assumptions*

- U.S.- wide air quality impacts of electrifying vehicles and off-road equipment were estimated for 2030
- Electrification reduces tailpipe emissions and emissions from petroleum refining, transport, and storage, but increases electricity demand
- The Electrification Case assumes that candidates for electrification are
  - approximately 17% of light duty and 8% of heavy duty vehicle, and
  - from 17% to 79% of various off-road equipment types
- The Electrification Case raises electricity demand by 5% over the 2030 Base Case
  - Nitrogen oxide (NOx) emissions are expected to decrease by 209 thousand tons (3%) overall
  - Emissions of other criteria pollutants also decrease

*Uarporn Nopmongcol et al., *"Air Quality Impacts of Electrifying Vehicles and Equipment Across the United States"*, Environ. Sci. Technol. 2017, 51, 2830–2837; DOI:10.1021/acs.est.6b04868

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Results of U.S. Air Quality Impacts Analysis for Vehicles Electrification

- Electrification resulted in net overall emissions decreases for all pollutants
- Emissions from Electric Generating Units (EGU) were shown to increase with higher demand:
  - SO_2 and NOx emissions from EGUs contribute less than 2% of the overall emission changes
- Increased electricity demand from electrified vehicles and equipment will:
  - introduce more natural gas-fired units
  - increase renewables and natural gas combined capacity to supply the additional load
  - displace power from coal-fired units at certain times of the day

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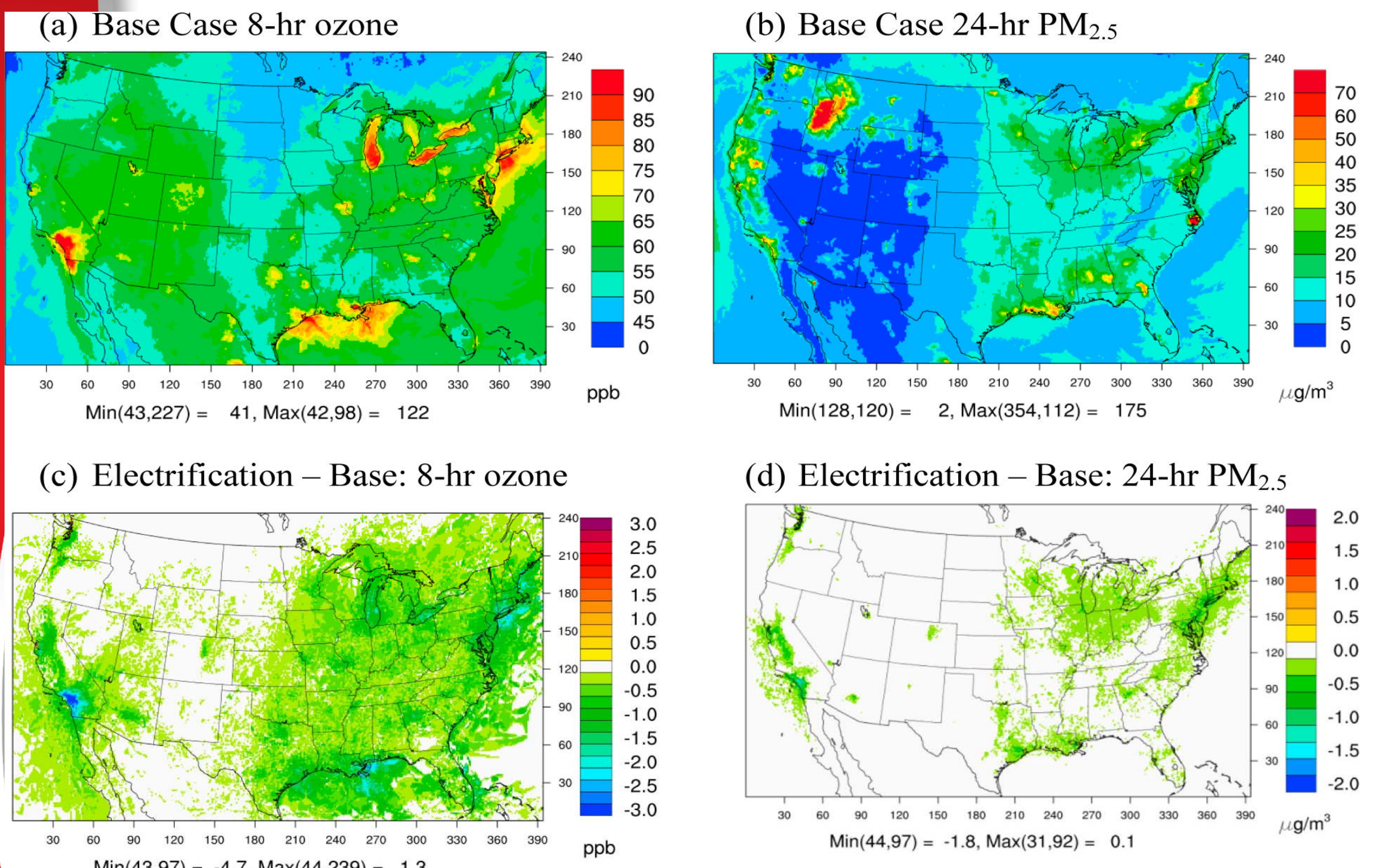
Changes in Concentrations of O_3 and $PM_{2.5}$



Source: Uarporn Nopmongcol et al

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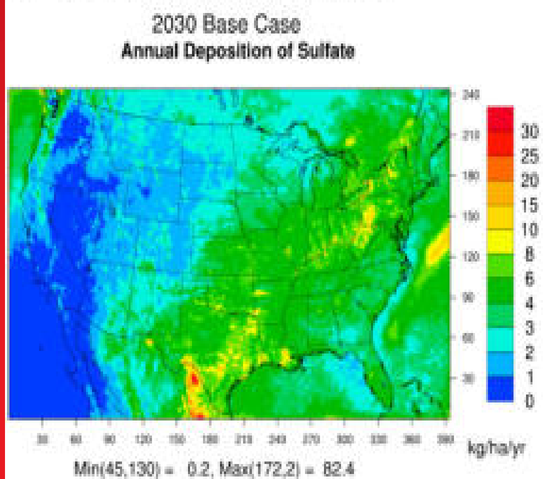
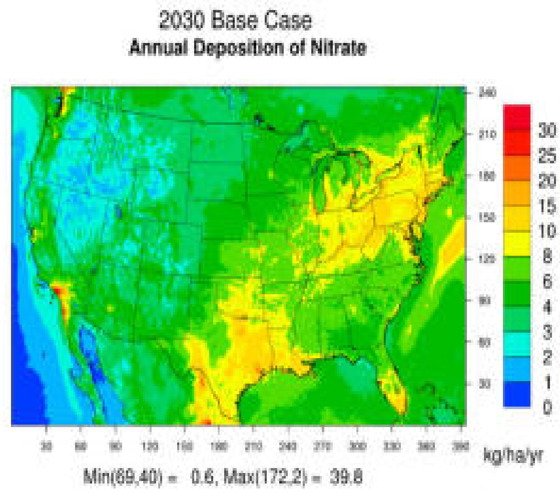
Changes in Acidic Deposition

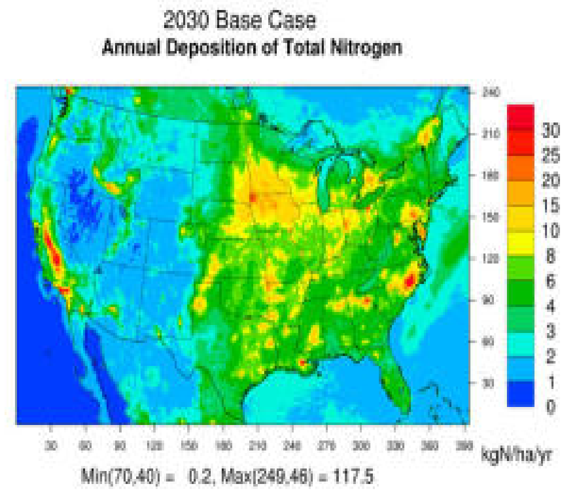
(a) Base Case sulfate deposition



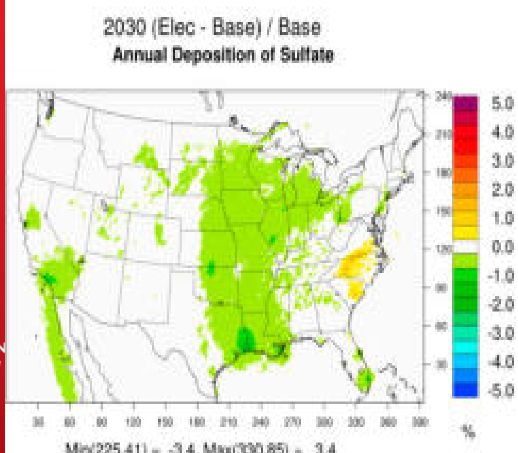
(b) Base Case nitrate deposition



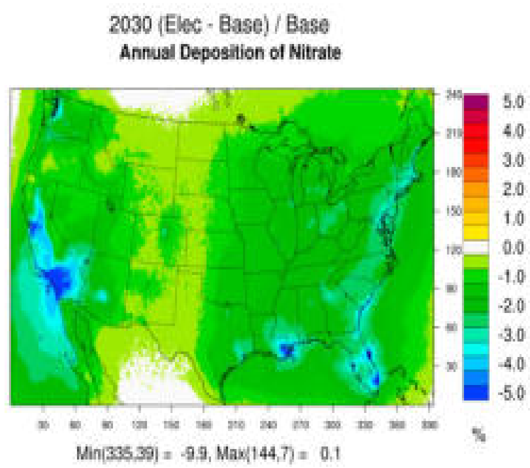
(c) Base Case total nitrogen deposition



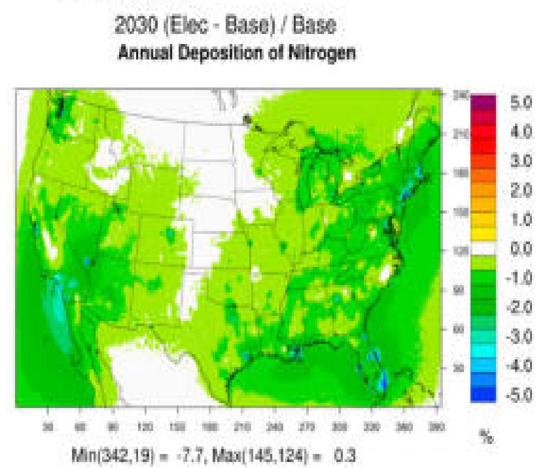
(d) Electrification – Base: sulfate deposition



(e) Electrification – Base: nitrate deposition



(f) Electrification – Base: total nitrogen deposition



Source: Uarporn Nopmongcol et al

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U.S. Air Quality Benefits from Electrification

- Air quality benefits of electrification are modest,
  - Ambient air concentration results in< 1 ppb reduction for ozone and 0.5 µg/m^3 for $PM_{2.5}$ – on average
  - Largest reductions for ozone and PM occur in urban areas
  - Reduced overall human exposure to both pollutants
- Electrifying off-road equipment may yield more air quality benefits than electrifying on-road vehicles
- Magnitude of modelled benefits from electrifying on-road vehicles in the U.S. are due to:
  - Assumptions on market penetration of HEV and EV
  - Conventional on-road vehicle emissions are already highly controlled by "Tier 3" standards
  - Electricity generation emissions are regulated and controlled

Benefits of Electrifying Off-road Equipment

- Additional off-road equipment electrification that contribute significantly to emission reductions:
  - Airport ground support equipment, e.g. forklifts,
  - Intermodal equipment, e.g. port cranes, yard trucks,
  - Shore-side (cold ironing) power for ocean-going vessels,
  - Switching locomotives and rail,
  - Transportation refrigeration units
- Reduced crude oil imports and associated marine vessel emissions cause additional benefits in port cities.
- Electrifying lawn and garden equipment, particularly mowers, could account for
  - about 48% reduction of total VOC emissions
  - More than 12% reduction of total NOx emissions

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Journal of Environmental Protection, 2013, 4, 1035-1043
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Scientific Research

Benefits of Reducing Air Emissions: Replacing Conventional with Electric Passenger Vehicles

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Methodology

1. **Energy mix for electricity production and related air emissions.** Assessment of anticipated air emissions from the projected electricity production mix (tons pollutant/kWh) for the different countries under study, for the year 2020.
2. **Passenger car stock and related emissions.** According to the national assessments of passenger car stock in 2020, we estimated air emissions from ICE vehicles according to Euro 6 standards and real-world emissions, under different scenarios of EV penetration to the market.
3. **Electricity needs for charging EV cars.** Calculation of the electricity needs for charging EV cars and the share of the additional needs in the overall electricity consumption was analysed for every country.
4. **Air emission costs.** Calculation of the externalities resulting from the electricity production needed for charging the EV cars compared to the air emissions from the same number of ICE vehicles.
5. **Quantification of benefits from reducing emissions by replacing conventional cars with EVs**.

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1. מקורות אנרגיה לייצור חשמל

Table 1. Projected share of fuel mix for electricity production for 2020.

	Denmark	France	Israel
Fossil energy			
Coal and lignite	27%		25%
Gas	22%		65%
Thermal		8.7%	
Oil	1%		
Non-fossil and RE			
Wind & other renewables	50%	4%	10%
Nuclear		73.7%	
Hydro		13.6%	

2. פליטות סגוליות מייצור חשמל

Table 2. Calculated air emissions from 1 kWh electricity production for year 2020.

Average Emissions (g/1kWh)	Denmark	France	Israel
CO_2	149.9	33.2	498
SO_2	0.05	0.08	0.18
NO_x	0.25	0.07	0.35
NMVOC	0.003	0.009	0.01
PM_{10}	0.003	0.005	0.03
As	1.46E−06	9.4E−07	Total Heavy metals (excluding Hg) 7.50E−05
Cd	2.8E−07	1.4E−07	
Cr	1.96E−06	2.1E−06	
Ni	1.5E−05	1.2E−05	
Pb	4.4E−06	2.3E−06	
Hg	1.6E−06	1.9E−07	1.5E−06
Dioxin	1.2E−11	1.4E−12	1.21E−12

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3. הערכת מספרי כלי רכב ונסועה

Table 3. Projected passenger cars (in millions) and average kilometers traveled for year 2020*.

	Denmark	France	Israel
Gasoline	1.72 (79.3%)	15.5 (45.1%)	2.6 (96.3%)
Diesel	0.45 (20.7%)	18.9 (54.9%)	0.1 (3.7%)
Total	2.17	34.4	2.7
Annual Average Kilometers Travelled (Km)	19,000	12,800	16,800
Annual Average Kilometers Travelled (Km) diesel	NA	16,000	NA
Annual Average Kilometers Travelled(Km) gasoline	NA	9,000	NA
Annual Average Kilometers Travelled	Urban (35%), Rural (46%), Highways (19%)	Urban (27.9%), Rural (44.5%), Highways (27.6%)	Urban (84.3%), Non-Urban (15.7%)

4. פליטות מרכבים יורו 6, כולל "עולם אמיתי"

Table 4. Emission limits of Euro 6 and real-world emissions (gr/km).

	CO	THC	THC + NO_x	NO_x	PM	CO_2
Diesel						
Euro 6	0.50	-	0.17	0.08	0.005	130
Real world		-		0.60		160
Gasoline						
Euro 6	1.0	0.10	-	0.06	0.005	130
Real world			-			160

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תרחיש		Share of EV (% of Total)	Share of Renewable Energy (%)	ICE emissions Euro 6 or Real World	Annual benefit (MEUR/year)
1	Denmark	3	50	Euro 6	7.8
2				RW	10.0
3		20		Euro 6	52.0
4				RW	66.8
5		40		Euro 6	103.9
6				RW	133.6
7	France	3	91.3	Euro 6	94.2
8				RW	146.1
9		20		Euro 6	628.1
10				RW	974.3
11		40		Euro 6	1256.2
12				RW	1948.5
13	Israel	3	10	Euro 6	4.1
14				RW	6.2
15		20		Euro 6	27.2
16				RW	41.2
17		40		Euro 6	54.4
18				RW	82.4

5. עלויות זה"א מתחבורה ומייצור חשמל

Table 5. Air emission costs in 2000 EUR/ton of substance emitted.

Substance		Costs of Air Emissions (2000 EUR/ton)		
		Denmark	France	Israel
NO_X	Road Transport	4400	7700	14,147
	Electricity production	4400	7700	3853
NMVOC	Road Transport	700	1400	4022
	Electricity production	700	1400	513
SO_2	Road Transport	5200	8000	8367
	Electricity production	5200	8000	6653
$PM_{2.5}$	Road Transport	185,768	216,706	27,328
PM_{10}	Electricity production	5475	11,486	9496
CO	Road Transport	500	500	1224

6. חישוב תועלות בהינתן שיעורי חדירת EV ושיעור האנרגיות החלופיות בתמהיל הדלקים לייצור חשמל

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מסקנות

1. ככל שתמהיל ייצור החשמל נקי יותר – התועלת עולה
2. ככל ששיעור חדירת החשמליות גבוה יותר- התועלת עולה
3. שימוש בנתוני פליטה אמיתיים (REAL LIFE) של רכבי מנוע שריפה פנימית מעלים את תועלת החשמליות
4. ככל שיש יותר נסועה עירונית- התועלת עולה