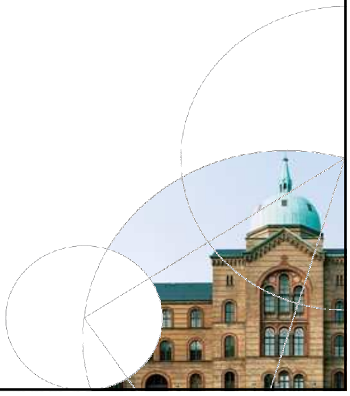
Faculty of Health Sciences

Health Impacts of Air Pollution in Denmark

August 27, 2012



Steffen Loft,
Section of Environmental Health,
Department of Public Health, Faculty of Health Sciences
University of Copenhagen, Denmark

Director of Institute for Environmental Evaluation (who took over from Bjørn Lomborg in 2004) left in 2006 after erroneous report on health and economic gains of particle filters on small diesel vehicles

Activities transferred to the Danish Economic Council in 2007

POLITIKEN.DK NYHEDER KULTUR SPORT DEBAT IBYEN FORBRUG REJSER ME

DANMARK

P Danmark Politik Internationalt Erhverv Klima Videnskab Ud

Annonce

LAVPRISKALENDEREN
Afgang
Copenhagen (CPH)
Destination
-Vælg destination-
Søg
norwegian.com

SENESTE NYT

17. AUG. KL. 15.07
Skak-legende anholdt foran Pussy Riot-retsbygning

17. AUG. KL. 15.05
Så går det løs! Stjernerne skal funkle i verdens bedste liga

17. AUG. KL. 14.55
Anklage: Livesex-folk vil bare score penge til klatgæld

17. AUG. KL. 14.44
Minister tvivler på, at alle kan redde dagpengene

17. AUG. KL. 14.34
Uenighed om tv-rettigheder var ved at udsætte ligaen

NAVNE

17. AUG. KL. 08.00
Fødselsdag
Kontroversiel

DANMARK 19. SEP. 2006 KL. 12.40

Lomborgs afløser går efter kritik

Direktør for Institut for Miljøvurdering, Peter Calow, fratræder. Han tager ansvaret for, at en rapport fra instituttet er ubrugelig på grund af fejl.

FACEBOOK SEND PRINT TIP OS

AF MARIE HJORTDAL

Direktøren for Institut for Miljøvurdering, Peter Calow, har sagt sin stilling op. Det skriver instituttet i en pressemeddelelse.

Kritik af rapport
Opsigelsen kommer angiveligt, efter at instituttets seneste rapport om virkningen af at montere partikelfiltre på små dieselbiler er blevet udsat for kritik.

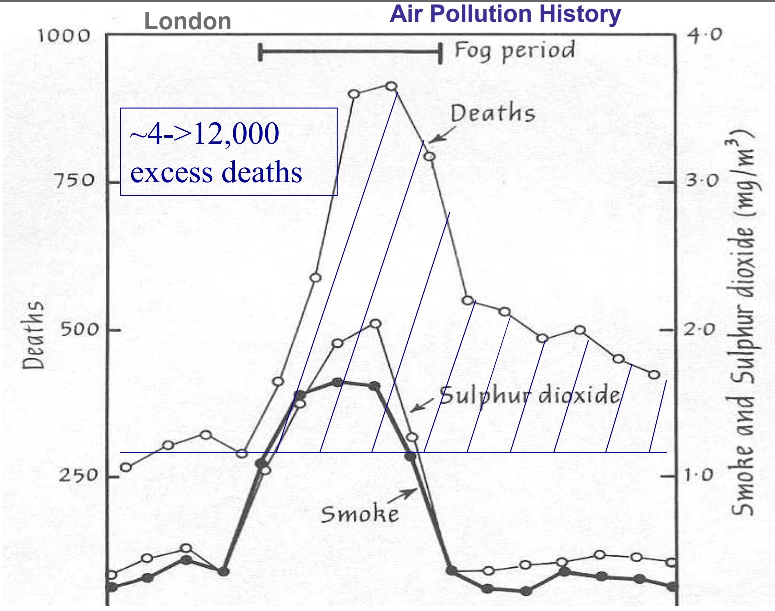
Rapportens resultater er blevet mødt med kritik og skepsis blandt både fagfolk og de politikere, den skulle vejlede. De mange kritikere har draget tvivl om rapportens konklusion om, at det vil kunne give en samfundsmæssig gevinst på 1,5 milliarder kroner at montere partikelfiltre på alle små dieselbiler.

»Jeg tvivler på, at effekten kan være sådan, som instituttet siger«, sagde Venstres miljøordfører Eyvind Vesselbo til Politiken.dk onsdag, efter rapporten blev offentliggjort.

Og under en gennemgang mandag, hvor instituttet gik igennem rapporten en ekstra gang for at svare igen på kritikken, opdagde man en regnefejl, der ændrer rapportens konklusion til det modsatte - der er ikke nogen samfundsøkonomisk gevinst på 1,5 milliarder kroner ved at indføre filtrene.

Vant til kritik
Peter Calow har været direktør for instituttet i to år, siden den omstridte

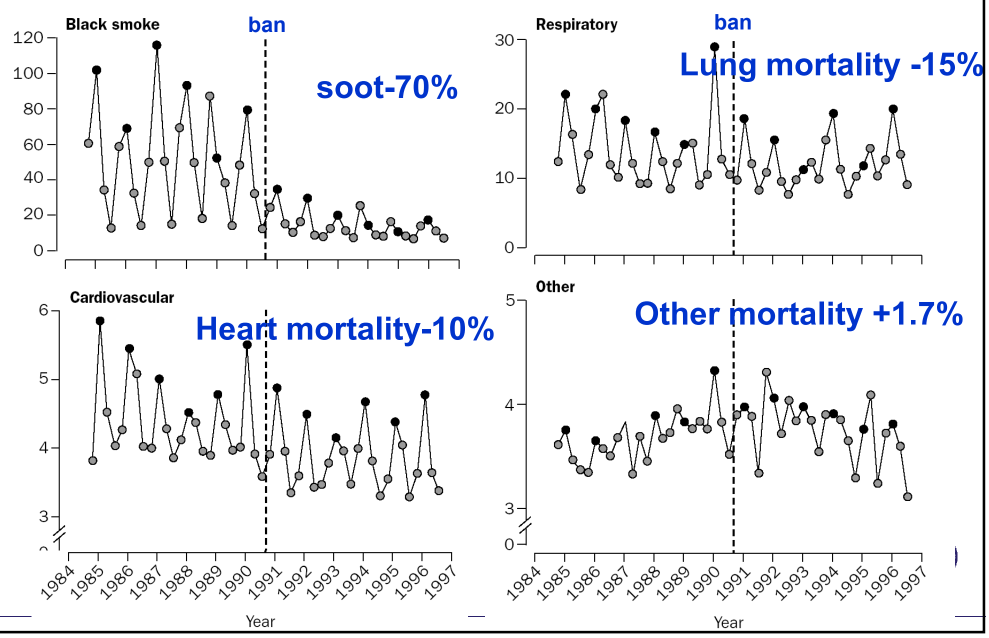
Air Pollution History



Ban on sea coal was enacted as early as 1306

Coal smoke and noise nuisance at domestic dwellings were dealt with by the London Assize of Nuisance as early as the 14th century.

Black smoke-soot and mortality per 1000 person yearss before and after ban of sale of coal in Dublin County Borough. *Clancy et al. Lancet 360: 1210–14, 2002*



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WHO estimate of environmental causes of death (x1000) globally in 2002

Countries according to income	poor	mid	rich	total
Total number of deaths annually	26.700	16.000	13.000	55.700
Lack of clean water and hygiene	1538	172	20	1730
Indoor use of solid fuel	1039	558	22	1619[a]
Occupationa exposures	2393	640	176	3209
Lead exposure	93	697	22	34
Urban air pollution	220	426	154	800[b]
Climate change	148	5	0	153
Total environmental deaths/year	5431	1870	444	7745

[a]Mainly due to airway disease among women and children
[b]Mainly due to cardiovascular disease > respiratory disease > lung cancer

UNIVERSITY OF COPENHAGEN Steffen Loft

Prüss-Ustün *et al. Environmental Health* 2011, **10**:9
http://www.ehjournal.net/content/10/1/9

ENVIRONMENTAL HEALTH

REVIEW **Open Access**

Knowns and unknowns on burden of disease due to chemicals: a systematic review

Annette Prüss-Ustün[1*], Carolyn Vickers[1], Pascal Haefliger[1], Roberto Bertollini[1,2]

Distribution of Disease Adjusted Life Years (DALYs) in burden of disease due to chemicals

Total 4.9 mill. deaths (8.3% of all)

Total 86 mill. DALYs (5.7% og all)

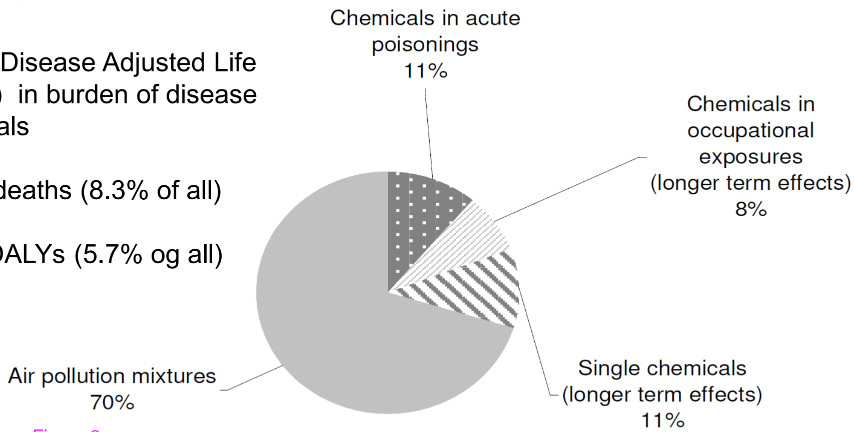
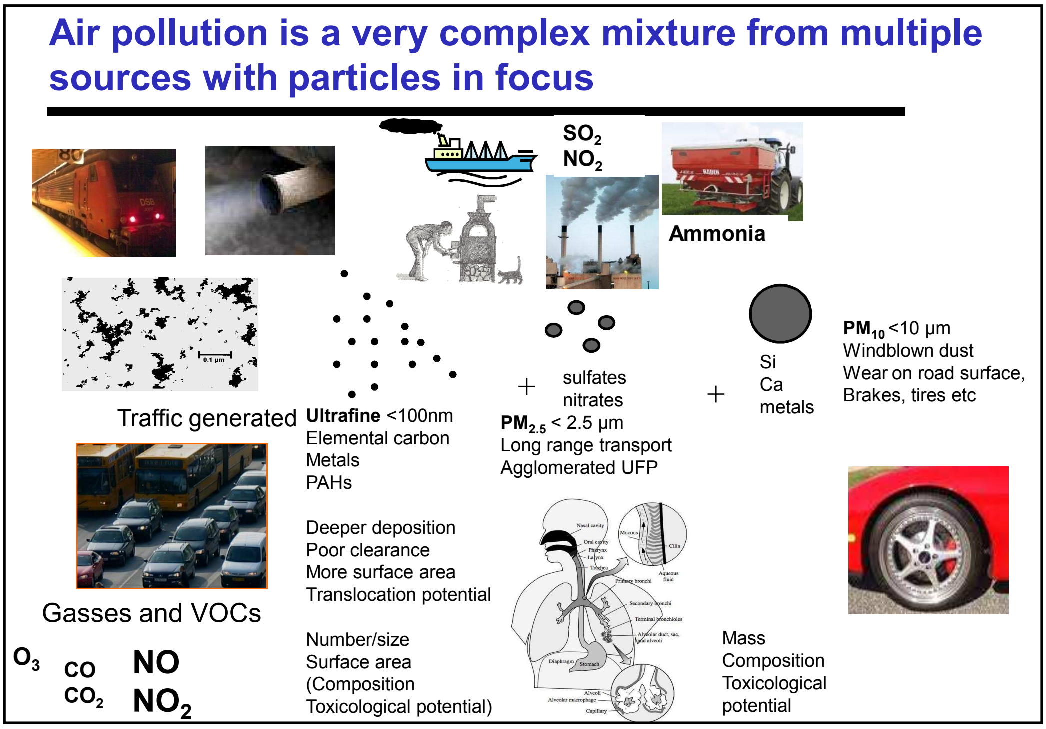
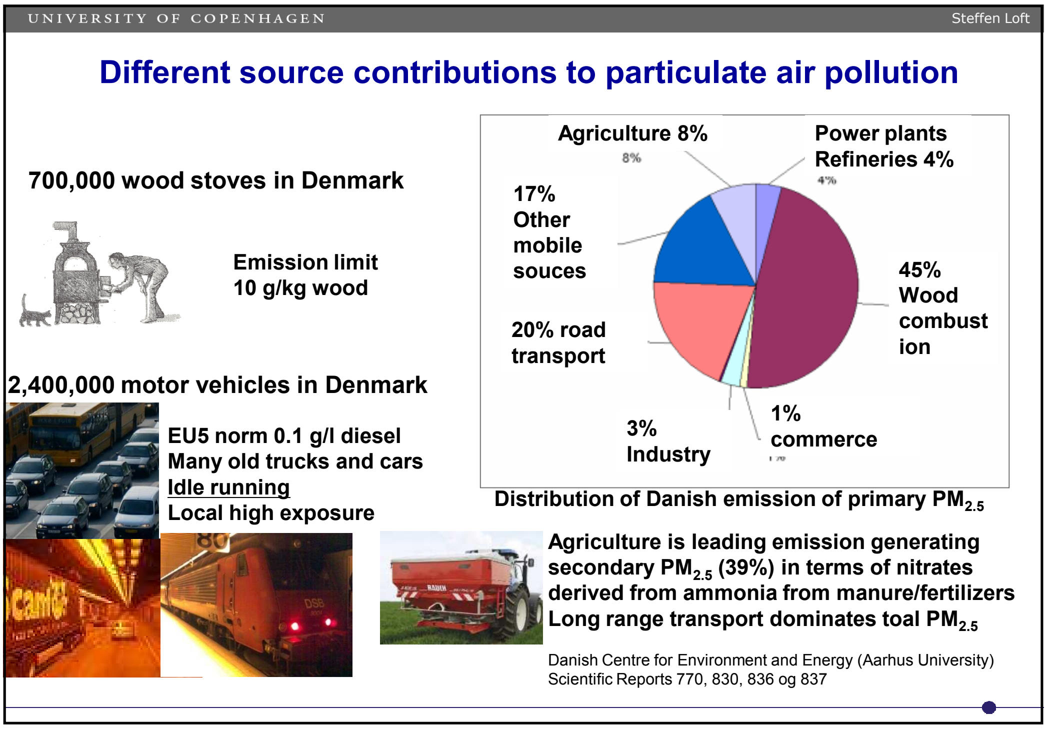
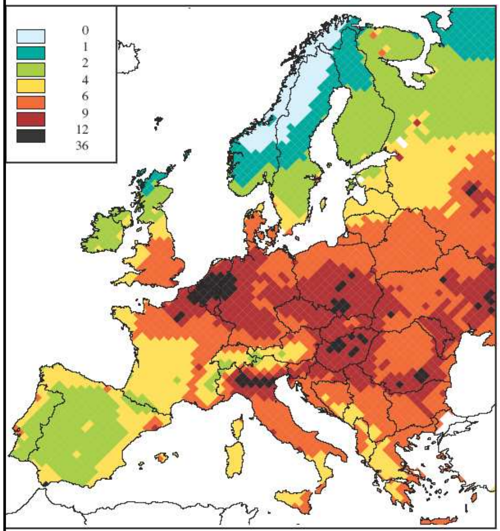


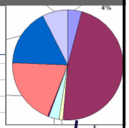
Figure 2

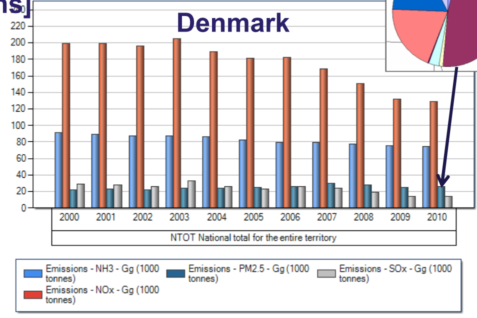

Air pollution is a very complex mixture from multiple sources with particles in focus
SO2
NO2
Ammonia
Traffic generated
Ultrafine <100nm
Elemental carbon
Metals
PAHs
sulfates
nitrates
PM2.5 < 2.5 µm
Long range transport
Agglomerated UFP
Si
Ca
metals
PM10 <10 µm
Windblown dust
Wear on road surface,
Brakes, tires etc
Deeper deposition
Poor clearance
More surface area
Translocation potential
Gasses and VOCs
O3
CO
CO2
NO
NO2
Number/size
Surface area
(Composition
Toxicological potential)
Mass
Composition
Toxicological
potential

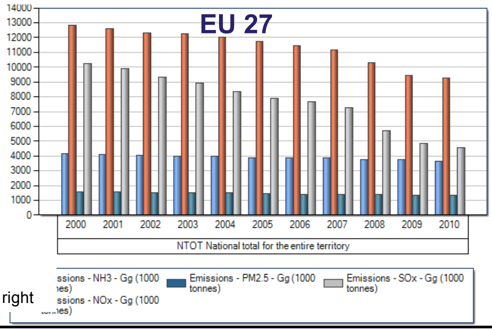

UNIVERSITY OF COPENHAGEN
Steffen Loft
Different source contributions to particulate air pollution
700,000 wood stoves in Denmark
Emission limit
10 g/kg wood
2,400,000 motor vehicles in Denmark
EU5 norm 0.1 g/l diesel
Many old trucks and cars
Idle running
Local high exposure
Agriculture 8%
Power plants
Refineries 4%
17%
Other
mobile
souces
45%
Wood
combust
ion
20% road
transport
3%
Industry
1%
commerce
Distribution of Danish emission of primary PM2.5
Agriculture is leading emission generating secondary PM2.5 (39%) in terms of nitrates derived from ammonia from manure/fertilizers
Long range transport dominates toal PM2.5
Danish Centre for Environment and Energy (Aarhus University)
Scientific Reports 770, 830, 836 og 837

Emission of primary and precursors of secondary $PM_{2.5}$ in DK and EU
Loss in life expectancy (year 2000) [months]

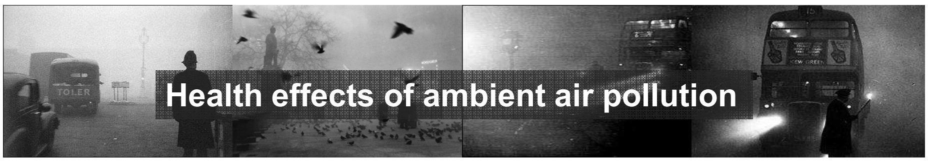








European Commision above
European Environmental Agency: Air Pollution Emission data viewer, right



Progression and mortality of cardiovascular and cerebrovascular disease and diabetes particularly among elderly — Long and short-term

Progression (cause of ?) and mortality of chronic obstructive lung disease particularly among elderly — Long and short-term

Cognitive dysfunction, aging, autoimmune diseases and ? — Long-term

Precipitation of asthma attacks in children and adults, progression, cause ?, sensibilisation/adjuvant effects — Long and short-term

Lung and probably other cancers

Reduced fetal growth, low IQ

Mortality
Reduced lung growth
IQ
— Long-term

Health Impact Assessment of Air Pollution

Requirements

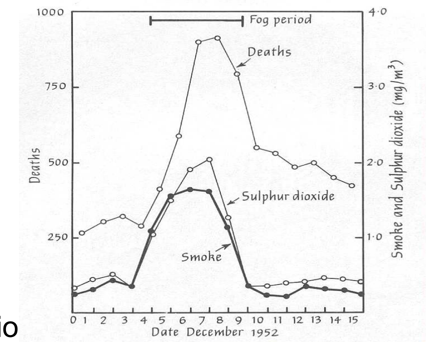
- **A population at risk (known demography and morbidity)**
- **Concentration-response functions for each air pollutant and combined for each outcome**
- **Exposure assessment**

Health impacts in terms of mortality, incidence of disease, morbidity, admissions, symptoms, sick leave, disability, medication etc. can be subject to valuation

Data for exposure-response functions for health impact assessment

Short term effects (acute)
time-series or panel

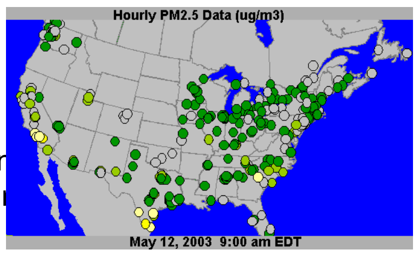
One or more urban areas
- Daily change in air pollutants (stations)
- Daily change in
  - Mortality including causes
  - Admssions, including causes
  - Symptoms in panel
  - Medicine consumption in panel/populatio

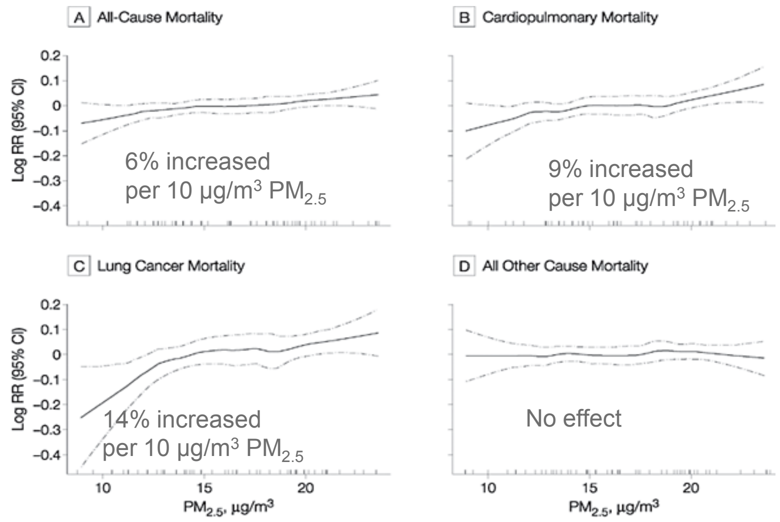


London december 1952

Long term effects (chronic)

Many urban areas with large cohort(s)
- populations of 8000-500.000) with known risk factors (life style, educatio
- Exposure (stations or model based on sou
- 10-20 years observation

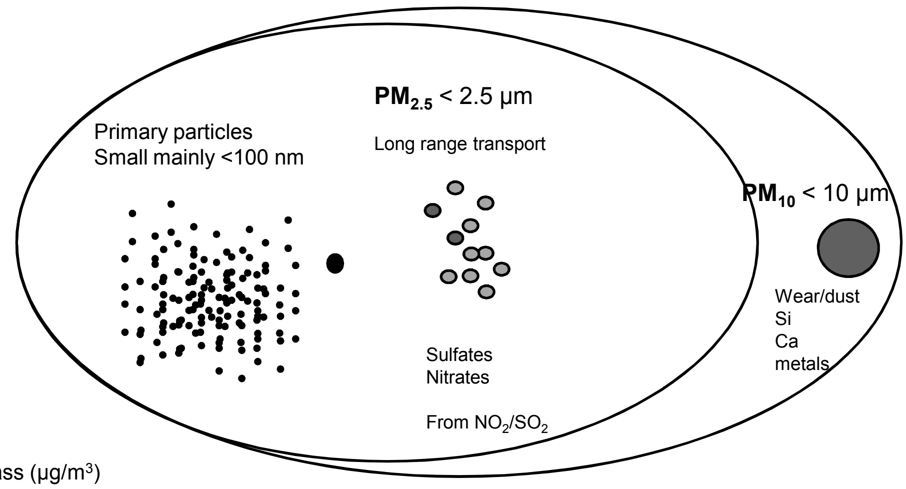




Long-term Cohort study

Non-parametric smothed exposure-response relationship – Log Relative Risk on µg/m³ $PM_{2.5}$ 1999-2000. Fig. 2. from Pope et al. JAMA 2002; 287:1132-41

American Cancer Society Cohort Study with 500.000 individuals from 51 city areas followed from 1979 to 2000. Recently updated with focus on analysis methodology and high spatial resolution in Los Angeles and New York (Krewsky et al. HEI 2009).



Mass (µg/m³)			
Rural	0.2 ?	12.6	7 – total 19.5
Urban background	0.5 ?	**13.1**	8 - total 21
Street	1 ?	19.5	14 - total 34

------------ HIA concentration-response function --------

Numbers (per/cm³)	
Rural	3,000
Urban background	7,000
Street	16,000

Danish Centre for Environment and Energy (Aarhus University)
Scientific Report 837

Simple Health Impact Assessment based on $PM_{2.5}$ in Denmark

Average levels of $PM_{2.5}$ for the general population 2008-2010

Rural	**12.6**
Urban background	**13.1**
Weigthed average	**13 µg/m³**

$$\Delta y = (y_0 \cdot pop)\ (e^{\beta \cdot \Delta x} - 1)$$

where y0 is the baseline rate, pop is the affected number of persons; ß is the exposure-response function (relative risk per change in concentration), and x is the estimated excess exposure.

13 µg/m³ corresponds to ca. 4000 of the 54000 (older than 30 years) dying annually

We do not know the naturally occuring $PM_{2.5}$ level but assuming it is 3 µg/m³

Anthropogenic 10 µg/m³ corresponds to ca. 3150 premature deaths annually

Rural urban difference of only 0.5 µg/m³ correponds to ca. 100 deaths annually

Estimated 3400 premature deaths annually in 2002 for anthropogenic PM_{10}
(Raascou-Nielsen Ugeskr. f. Læger 2002)

Centre for
Energy, Environment and Health
Report series

ISSN 1904-7495

CEEH Scientific Report No 7a

Description of the CEEH health effects model - selection of concentration-response functions

Concentration-response functions

For $PM_{2.5}$, PM_{10}

Table 3. Concentration response functions proposed for use in the CEEH health effects model

Pollutant	Effect	Age	ICD-10	CRF (RR)	Notes
Ozone	Mortality of any respiratory	All ages	J00-99	1.04 (1.013-1.067) per 10 ppm in summer months mean of 1-hr max	No threshold. Only April – September.
$PM_{2.5}$	Cardiopulmonary mortality	30+	I10-70 + J00-99	1.09 (1.03-1.16)	
$PM_{2.5}$	Lung cancer mortality	30+	C33-34	1.14 (1.04-1.23)	
$PM_{2.5}$	Respiratory hospital admissions	all ages	J00-99	1.0114 (1.0062-1.0167)	
PM_{10}	Ischemic heart disease hospital admissions	all ages	I20-25	1.008 (1.005-1.01)	
PM_{10}	Dysrhythmia hospital admissions	all ages	I47-49	1.008 (1.001-1.014)	
PM_{10}	Heart Failure hospital admissions	all ages	I50	1.014 (1.005-1.024)	
PM_{10}	Infant mortality	0-1		1.04 (1.02-1.07)	
PM_{10}	Lower respiratory symptoms	symptomatic adults		1.3 days/yr/person*	
PM_{10}	Lower respiratory symptoms	5-14		1.86 days/yr /person*	
$PM_{2.5}$	Restricted activity days	15-64		0.902 days/yr /person*	
$PM_{2.5}$	Work Loss days	15-64		0.207 days/yr /person*	
NO_2	COPD incidence	adult	J41-44	0.483% (0.068-0.8979)	
SO_2	All-cause mortality	Adult	A00-Y98	1.012 (1.007-1.016) per 10 µg/m³	24h previous day mean
PM_{10}	New cases of chronic bronchitis	27+	J41-44 + J47	1.098*	sensitivity analysis
$PM_{2.5}$	All-cause mortality	30+	A00-Y98	1.06 (1.02-1.11)	sensitivity analysis
PM_{10}	Cardiac hospital admissions	all ages	I00-52	1.009 (1.007-1.01)	sensitivity analysis
$PM_{2.5}$	Incidence of fatal cardiovascular disease	adult	I21-25 + I61-69	females 100% males 50%*	sensitivity analysis

Recommended CRF (**for yearly means of a 10 µg/m³ if not specified otherwise**) in CEEH to be used as

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Report series

CEEH Scientific Report No 3:

Assessment of Health-Cost Externalities of Air Pollution
at the National Level using the EVA Model System

Total years of life lost

Europe	7,220,000
Denmark	42,700

Due to all emissions

Europe	49,000
Denmark	8,520

Due to Danish emissions

as calculated for mainly $PM_{2.5}$ Mass by the EVA model from Danish Centre for Environment and Energy (Aarhus University)

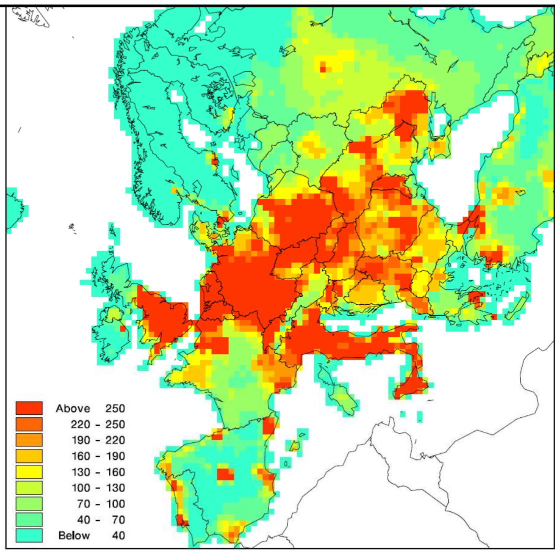

Figure 5: Number of premature deaths per grid cell in Europe (DEHM model domain 2) a lated with the integrated EVA model system for the year 2000 for the total air pollutio (scenario All/all). The area of the grid cells are 50 km x 50 km = 2500 km^2 so the colors ref number of premature deaths per 2500 km^2. The total number of premature deaths in th model domain is 680000, calculated from the number of chronic YOLL (see table 9) divid factor of 10.6 (as used in the CAFE; Watkiss et al., 2005). High numbers of premature d shown in the map, require both high levels of annual particle concentrations and high po density.

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CEEH Scientific Report No 3:

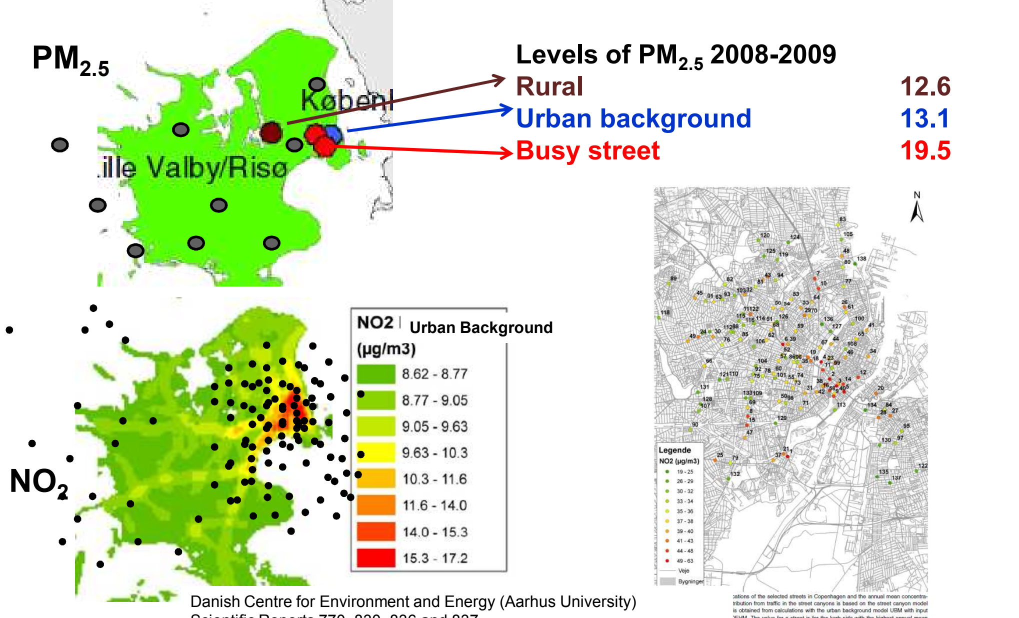
Assessment of Health-Cost Externalities of Air Pollution
at the National Level using the EVA Model System

Cost of health effects of emissions from Danish sources

	All Europe	In Denmark
Major central power plants	10.3 %	5.7 %
Domestic heating, incl. Wood stoves	9.3 %	16.3 %
Power plants related to industrial production	5.3 %	4.3 %
Production processes, e.g. cement, paper, metals	1.9 %	3.1 %
Extraction and distribution of fossil fuels	1.7 %	2.3 %
Use of solvents, e.g. in paint	2.6 %	2.5 %
Road traffic	17.6 %	19.3 %
Other mobile sources (tractors, lawn movers etc.)	7.9 %	7.2 %
Waste handling and combustion	0.6 %	0.1 %
Agriculture	42.8 %	39.4 %
Sum	100 %	100 %
Sum in billion Euro	4.9	0.8

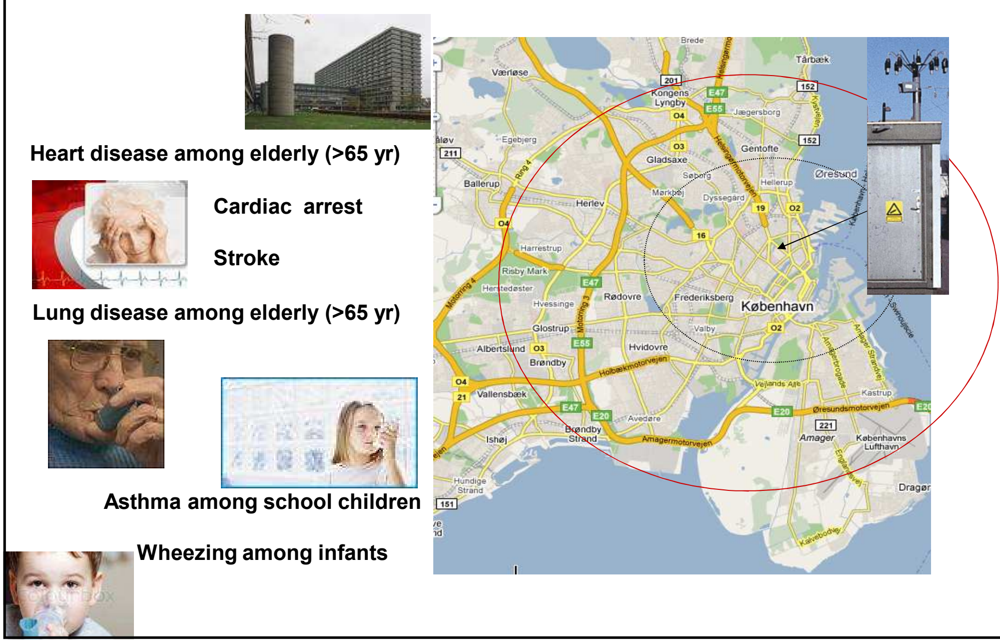
Based on direct effects of primary $PM_{2.5}$, CO and SO_2 and indirect effects via ozone and NO_2 and SO_2 generating secondary $PM_{2.5}$

Uniform levels of $PM_{2.5}$ in most of Denmark related to long-range transport
Large gradients in small combustion particles and NO_2 from traffic



Danish Centre for Environment and Energy (Aarhus University)
Scientific Reports 770, 830, 836 and 837

Time-series and case-cross-over studies on associations between air pollutants and short-term health outcomes in Copenhagen - sizes and sources

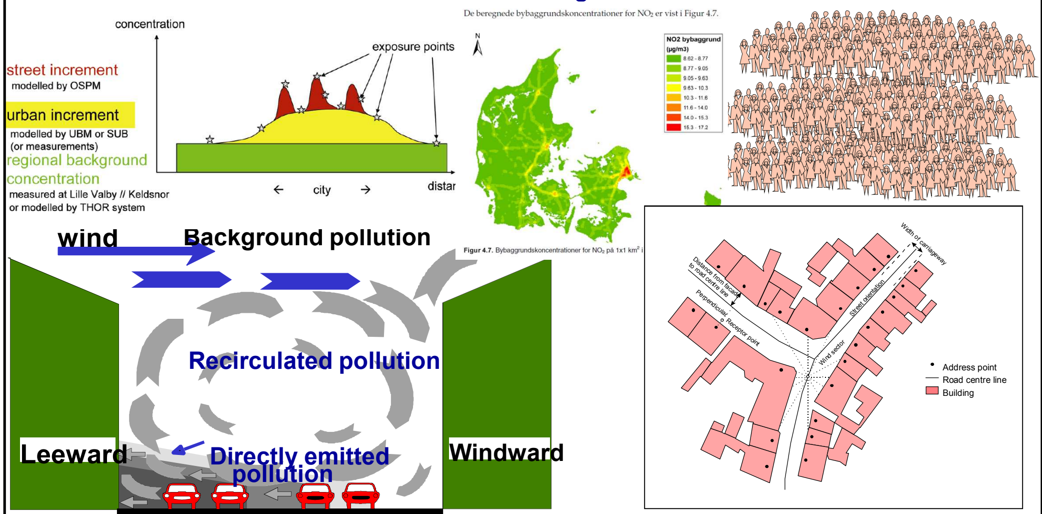


Time-series and case-cross-over studies on associations between air pollutants and short-term health outcomes in Copenhagen

Associations in multipollutant Models	PM_{10} mass	PM_{10} daily component	$PM_{2.5}$ mass	Particle count	NO_2	CO
Cardiovascular admission (>65 yr)	++	crustal	+	-	+	-
Out-of-Hospital Cardiac Arrest (no hourly assoc)	+		+	-	-	(+)
Ischemic likely thrombotic stroke	(+)			+	(+)	(+)
Respiratory admissions (65 yr)	++	biomass	+	(+)	+	-
Asthma admissions (0-18 yr)	++	vehicle	+	-	+	-
Wheezing (0-1 yr)	+			+	(+)	(+)
d.o. (0-3 yr)	(+)			-	+	(+)

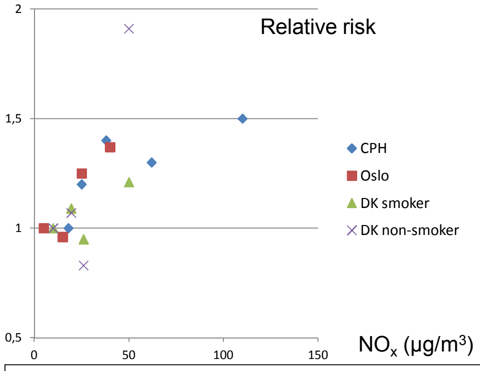
Andersen et al. JESEE 17: 625-36, 2007; Occup Envir Med 65: 458-66, 2008; Thorax 63: 710-6, 2008; ; Eur Heart J 31: 2034-40, 2010
Wichmann et al: Int J Envir Res Pub Health 8: 3712-27, 2011; PLoS One 6:e22904, 2011; Environ Health 11:19, 2012; PLoS One in revision
Iskandar et al. Thorax 67:252, 2012

AIRGIS model for assessment of exposure in terms of Nox and NO2 at at residences from 1971 onwards at follow up of 57 053 participants in the Danish Diet, Cancer and Health cohort from baseline in 1993–1997 through 2009.



CVR ↔ MR ↔ Traffic ↔ BBR ↔ >30 yr exposure at 300,000 addresses ↔ CPR

Environmental Sciences, Aarhus University: Ole Hertel, Sten S. Jensen, Martin Hvidberg, Matthias Kettzel



Dose response in cohort studies of lung cancer risk related to modeled traffic exposure as NOx at the address for 10-40 years

Raaschou-Nielsen et al. CEBP 2010 (CPH)
Nafstad et al. Thorax 2003 (Oslo)
Raaschou-Nielsen et al. EHP 2011 (DK)

Linear dose-response estimates in cohort studies of lung cancer risk related to traffic exposure as NOx at the address for 4-40 years

Study	relative risk (95% CI)	per increment of
CPH, Raaschou-Nielsen et al. CEBP 2010	1.37 (1.06-1.76)	100 µg/m³ NOx
DK, Raaschou-Nielsen et al. EHP 2011	1.09 (0.79-1.51)	100 µg/m³ NOx
Oslo, Nafstad et al. Thorax 2003	1.08 (1.02-1.15)	10 µg/m³ NOx
Oslo, men 51-70 yr, Næss et al. Am J Epidemiol	1.07 (0.97-1.18)	22 µg/m³ NO_2
Oslo, women 51-70 yr, Næss et al. Am J Epidemiol	1.23 (1.10-1.38)	22 µg/m³ NO_2
PAARC France, Filleul et al. OEM 2005	1.48 (1.05-2.06)	10 µg/m³ NO_2
NLCS-Air, Beelen et al. EHP 2008	0.91 (0.72-1.15)	30 µg/m³ NO_2
EPIC, Vineis et al. IJC 2006	1.14 (0.78-1.67)	10 µg/m³ NO_2
ACS, Krewski et al. HEI 2009	0.99 (0.97-1.01)	10 ppb NO_2
Shizuoka, Yorifuji et al. OEM 2010	1.30 (0.85-1.93)	10 µg/m³ NO_2

Danish Diet, Cancer and Health Cohort study of air pollution lung effects

57 053 participants (aged 50-65 years) mainly from Copenhagen were recruited 1993-1997
Follow-up through 2006 for diagnoses of lung cancer or first admission for asthma or chronic obstructive lung disease (COPD). Exposure assessment in terms of NOx or NO_2 modelled at all adresses from 1971 to censoring of all subjects (>200,000 addresses).

Hazard ratio*	all	current smokers	never smokers
Lung cancer (592 cases) Per 100 µg/m³ NOx	1.09 (0.79-1.55)	1.02 (0.71-1.46)	1.51 (0.72-3.16)
Asthma (997 cases) Per IQR in NO_2	1.13 (1.04-1.22)	1.15 (0.95-1.35)	1.03 (0.88-1.18)
COPD (1797 cases) Per IQR NO_2	1.08 (1.02-1.14)	1.07 (1.00-1.14)	1.08 (0.85-1.30)

*Adjusted for Smoking Status, Smoking Duration, Smoking Intensity, environmental tobacco smoke, body mass index, education, occupational exposure, (and fruit consumption)

Raschou-Nielsen Environ Health Perspect 2011; Andersen et al. Thorax 2012o, Am J Resp Med Crit Care Med 2011

Air pollution from traffic and cancer risk in a cohort study

Raaschou-Nielsen *et al. Environmental Health* 2011, **10**:67
http://www.ehjournal.net/content/10/1/67

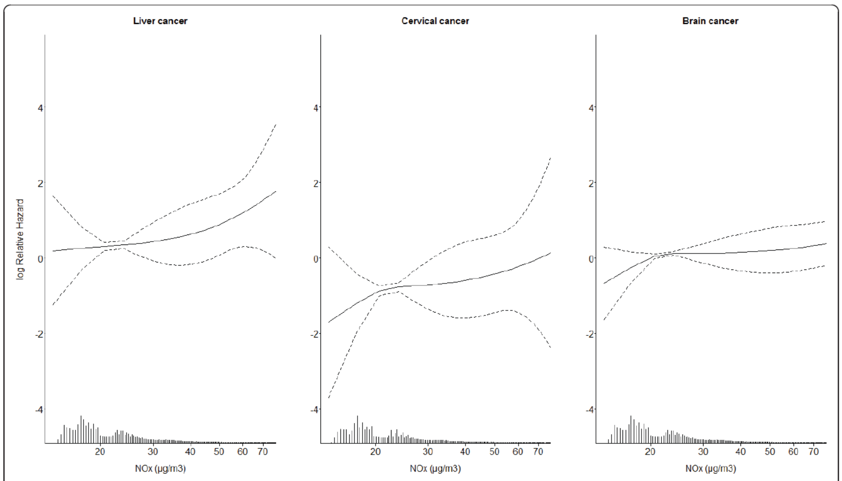
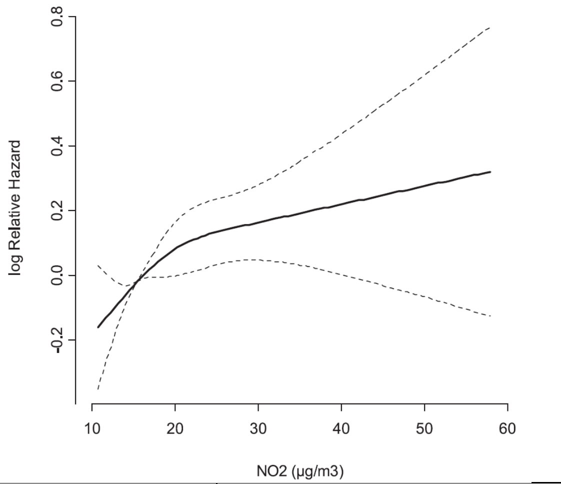


Figure 1 Non-linear exposure-response functions (filled lines; 95% confidence limits indicated by dashed lines) between average NO_x concentration (µg/m^3) at residences from 1971 onwards and risks for primary liver cancer, cervical cancer and brain cancer. The functions were adjusted for cancer-specific sets of potential confounders, listed in the last column of Table 2. The figure includes the exposure range between the 5^{th} and 95^{th} percentiles (14.8-69.4 µg/m^3 NO_x). The exposure distribution is marked on the x-axis.

Air pollution from traffic and diabetes incidence in a cohort study



Association between exposure to NO_2 levels (log transformed) at residence and incident diabetes defined by strict definition (n = 2877) (log relative hazard with 95% confidence interval) for 51 818 DCH cohort members, adjusted for gender, BMI, waist-to-hip ratio, smoking status (never, previous, current), smoking intensity, smoking duration, environmental tobacco smoke, physical activity, alcohol intake, fat intake, and educational level.

Andersen et al. Diabetes Care 35: 92-8, 2012

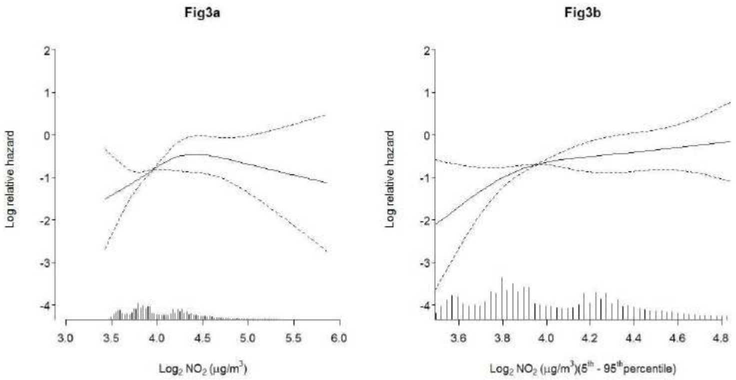
	Diabetes Original* *n = 4 040*			**Diabetes Strict*** *n = 2 877*		
	Adjusted for age	**Fully adjusted†**	**Fully adjusted†** + hypertension, hypercholesterolemia, and MI	**Crude** Adjusted for age	**Adjusted†**	**Adjusted†** + hypertension, hypercholesterolemia, and MI
	HR (95%CI)	**HR (95%CI)**	**HR (95%CI)**	**HR (95%CI)**	**HR (95%CI)**	**HR (95%CI)**
NO_2† (µg/m³) 1971-follow-up	1.06 (1.03-1.09)	1.00 (0.97-1.03)	1.00 (0.97-1.04)	1.11 (1.07-1.15)	1.04 (1.00-1.08)	1.04 (1.00-1.08)

Risk of mortality from diabetes in relation to average log-NO_2 concentration (µg/m^3) at residences from 1971 onwards at follow up of 52 061 participants in the Danish Diet, Cancer and Health cohort from baseline in 1993–1997 through 2009.

Mortality rate ratio was 1.62 (1.04-2.50) per doubling of NO2 concentration

Whole cohort

Cohort members with NO_2 exposure between the 5th and the 95th percentile



Functions adjusted for for sex, age, calendar year, length of school attendance, occupation with potential for exposure to smoke and fumes, smoking status, smoking intensity, smoking duration, environmental tobacco smoking, alcohol, fat, fruit and vegetables, body mass index, waist circumference, physical active with sport, hypertension and hypercholesterolemia at baseline.

Raaschou-Nielsen et al. Diabetologia in press

Stroke and Long-Term Exposure to Outdoor Air Pollution From Nitrogen Dioxide : A Cohort Study

Zorana J. Andersen, Luise C. Kristiansen, Klaus K. Andersen, Tom S. Olsen, Martin Hvidberg, Steen S. Jensen, Matthias Ketzel, Steffen Loft, Mette Sørensen, Anne Tjønneland, Kim Overvad and Ole Raaschou-Nielsen

Stroke 2012, 43:320-325

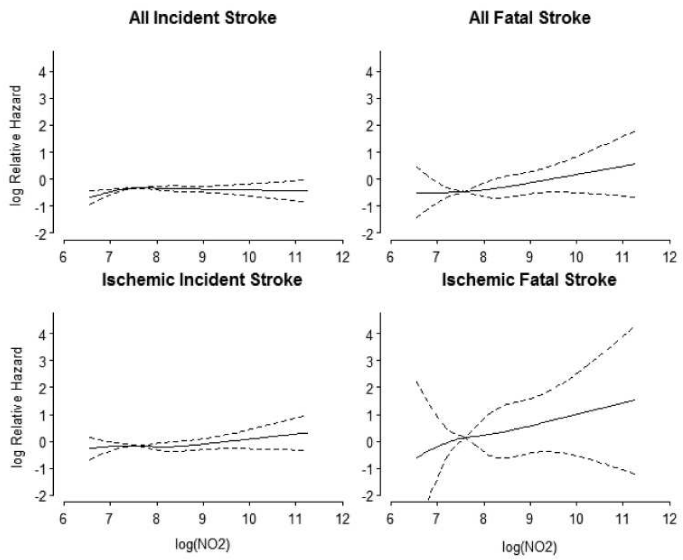
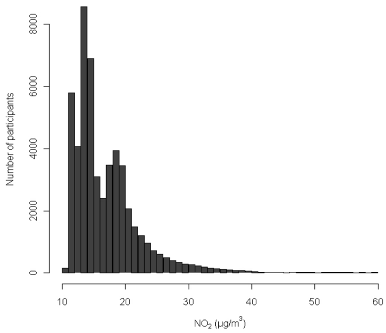
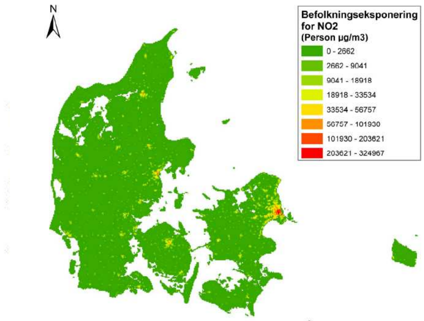


Figure. Exposure–response relationship between NO_2 and incident (left total, n=1984; right ischemic n=629) and fatal (left total n=142; right ischemic, n=23) stroke among 52 215 participants in the Diet, Cancer, and Health cohort members. NO_2 indicates nitrogen dioxide.

Very crude mortality impact assessment of traffic pollution in Denmark





Figur 4.11. Befolkningseksponering for NO_2 i 2008 på 1x1 km² baseret på bybag-grundskoncentrationer efter SUB-metoden samt befolkningsdata fra CPR.

Danish Centre for Environment and Energy (Aarhus University)
Scientific Reports 770, 830, 836 og 837

Concentration-response: 13% increase in all cause mortality for an increase of 9-10 µg/m³ e.g. from rural to urban levels of 18-20 µg/m³ and corresponding to international concentration-responses

25% of a study population mainly from greater Copenhagen and Aarhus had ≥19 µg/m³ time weigthed at street door

Integrating across such a population indicates around 10% of total mortality was related to NO_2 levels (probably as indicator of mixed air pollution especially combustion particles) .

This corresponds to around 400 of the current mortality of 4400 in Copenhagen City

More exposed than average Danish population and total cost could be around 2500 premature deathhs

Congestion charges and health impact

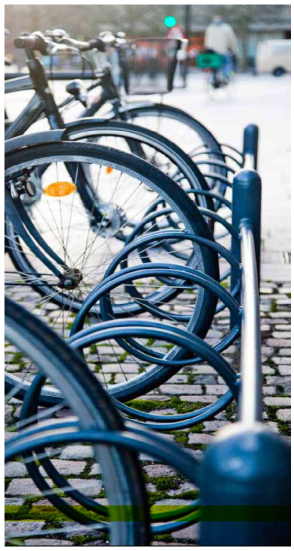
Limited effect on total mass of $PM_{2.5}$
Small mass of
• primary (tail pipe ultrafines) and
• secondary $PM_{2.5}$ from NO_2
Corresponding to 2-3 premature deaths spared

Danish Centre for Environment and Energy (Aarhus University)
Scientific Report 16, 2012

However, 6-7% reduction in NO_2 at 135 modeled street sites

This would correspond to 0.6-0.7% reduced mortality or around 30 spared premature deaths in Copenhagen City assuming that NO_2 is representative for alll traffic-related pollutants with health impacts

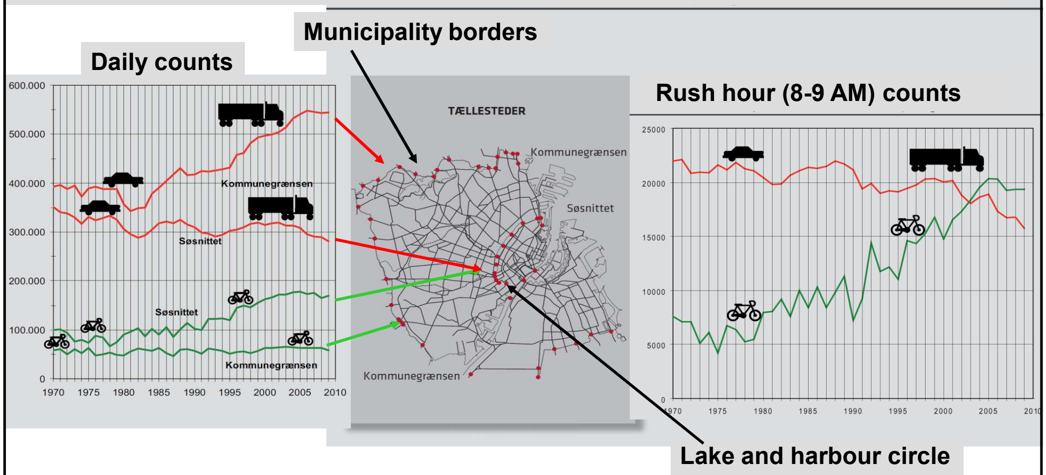
Despite nice pictures, the Climate Commision has not included active or public transport or health savings from reduced air pollution in scenarios
Claim: Extensive transfer of transport in cars to cycling can only reduce energy consumption by 2.5% (despite that transport accounts for 1/3 of all energy)



Of people living and working within Copenhagen City 55% cycle to work

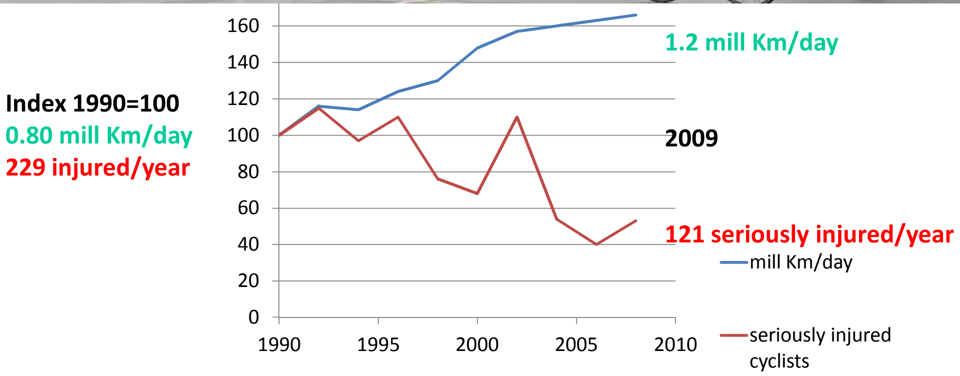
Of people working in Copenhagen City 38% cycle to work

Traffic counts in Copenhagen 1970 to 2010



500,000 inhabitants within municipality borders of 10 km diameter
1,500,000 inhabitants in greater Copenhagen 25 km diameter

Cycling policy and development 1990-2010 in Copenhagen



Mill km between injuries		1.2	2.4	4.2	
Fatal accidents/yr			3-5		1-2
Bike lanes (km)		294	323	332	350
Green routes (km)	0	14	18		
Commuters cycling (%)		30	32	37	

Cycling decreased by 23% in this period in the rest of Denmark

Commuting by cycling in the Copenhagen City Heart Study

Totally ca. 20.000 persons (age 20-65 years) started in 1976:

- 28% (11%-45%) reduced mortality among those out of 6954 who cycled to work

- after 15 years mean follow up

- With control of relevant confounders (Age, sex, education, leisure activity, BMI, blood lipids, smoking, blood pressure)

(Andersen et al. *Arch Int Med* 160:1621-8, *2000***)**

Simple co-benefit analysis of current cycling in Copenhagen

Transport	million km per year	CO_2 emission ton per year	lives lost/gained per year
Car travel	1,240	257,000	5 lost to accidents 160 lost to air pollution[1]
Cycling	427	0[4]	762 gained due to exercise[2] 8 lost to air pollution[3]

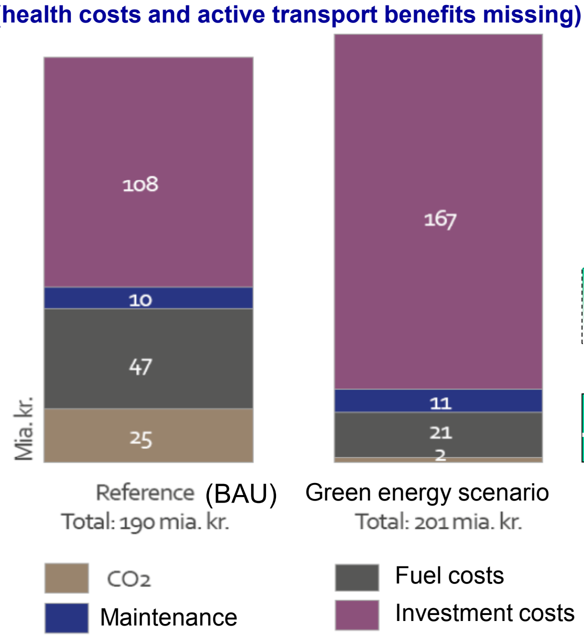
[1] Assuming that 40% of air pollution here in terms of NO_2 is related to car travel and a dose response-relationship from Danish and other European cohort studies indicating a 13% increase in mortality per 9-10 ug/m3 increase in NO_2 at street door,

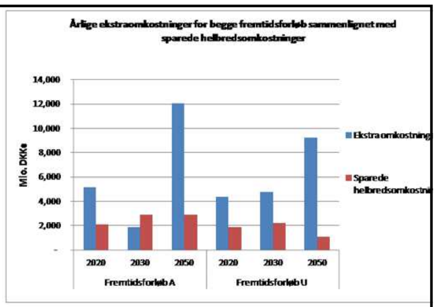
[2] Assuming that 50% of Copenhagen citizens cycle to work and that cycling is associated with a 28% reduced mortality (Andersen et al. 2000)

[3] Assuming that 24-h exposure is increased by 5% by biking for 1 hour in traffic

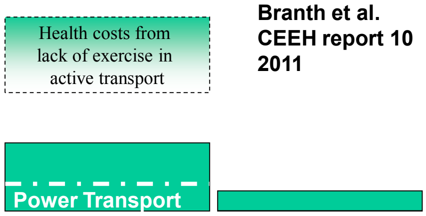
[4] Saved 88,500 ton CO[2] assuming the same transport work by car (i.e. 0.15% of total Danish emission)

Society costs of energy systems in 2050
(health costs and active transport benefits missing)





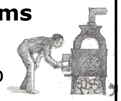
Branth et al. CEEH report 10 2011



Emission health costs 2006 by EVA model (Brandt et al 2009)

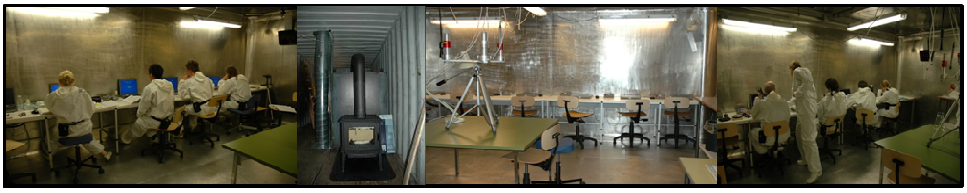
Green energy 2050

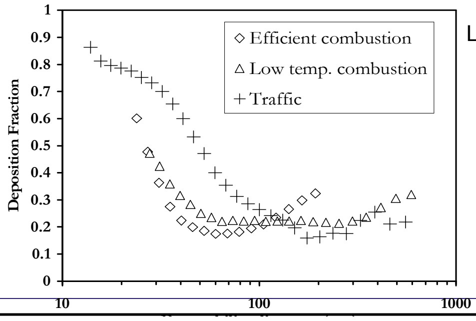
Biomass particle emission – how does that compare to traffic in health terms



Controlled exposure to high concentrations of wood smoke up to 400 µg/m³ had no effect on vascular or lung function and minimal effect on only very few of markers measured in the blood.

Consistent lung and vascular effects of similar diesel or traffic exposure



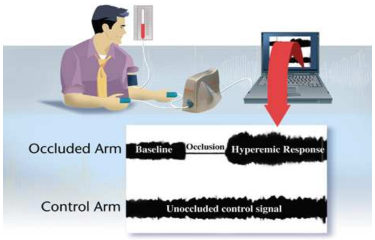


Low deposition of wood smoke in airways ?
but emission standards much higher

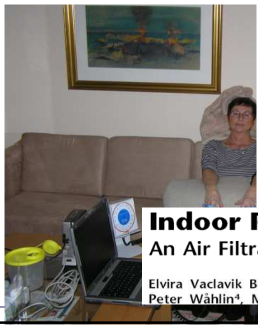
Danielsen et al. Mutat Res 2008
Sehlstedt et al. Particle Fibre Toxicol 2010
Forchammer et al. Particle Fibre Toxicol 2012
Forchammer et al. Particle Fibre Toxicol 2012
Pope et al J Air & Waste Manage Assoc 2011
Löndahl et al. Env Sci T echn 43:4659-64, 2009
Löndahl et al. Inhal Toxicol 20; 923-33, 2008

Steffen Loft

Endothelial function measured as peripheral artery tone in index finger after forearm ischemia



Intervention study with 21 married elderly (>60 yr) couples living in apartments at busy streets in Copenhagen. Air filtered for all particles or not and monitored for 2 x 48 hours. Focus on vascular function relevant for risk of heart disease and mortality



Endopat score increased by intervention: 8% (1%-16%; 95% CI; p=0.03)

No inflammation signs

Am J Resp Crit Care Med 2008

Indoor Particles Affect Vascular Function in the Aged

An Air Filtration–based Intervention Study

Elvira Vaclavik Bräuner[1], Lykke Forchhammer[1], Peter Møller[1], Lars Barregard[2], Lars Gunnarsen[3], Alireza Afshari[3], Peter Wåhlin[4], Marianne Glasius[4], Lars Ove Dragsted[5], Samar Basu[6], Ole Raaschou-Nielsen[7], and Steffen Loft[1]

Conclusions and summary

Health Impact Assessment of air pollution is complex and has so far only addressed evenly distributed air pollutants especially secondary and long-range transport-dominateded $PM_{2.5}$ mass without source specific characteristics or local gradients due to e.g. traffic

Based on the classic pollutants mainly determined by $PM_{2.5}$ mass health effects include

Years of life lost	Europe	Denmark
All emissions	7,220,000	42,700 ≈ 3000 anthropogenic premature deaths
Danish emissions	49,000	8,520

However local traffic emitting ultafine particles and gasses with so far poorly assessed concentration-response are lacking. By means of a series of cohort studies with traffic-related exposure gradients modelled as NO_2 or NO_x we can estimate the population-related health costs

Estimated by this model and very rough exposure estimates traffic emissions cost around another 2500 premature deaths on top of the 3000 related to $PM_{2.5}$ although some overlap is likely

Active transport such as cycling has substantially more health benefit for both individual and society than the small excess risk due to more exposure to air pollution

Other local sources such as wood combustion has yet to be addressed but human exposure studies suggest less effect than related to traffic sources on mass basis but exposure higher

Indoor air filtration is likely to reduce risk of living in polluted areas for susceptible people