BRIDGING THE GAP: USING SCIENCE TO INFORM THE DEVELOPMENT OF POLICY
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NATIONAL INSTITUTE FOR HEALTH AND WELFARE

Applying new methodologies to Indoor Air

Matti Jantunen, research professor
National Institute for Health and Welfare (THL)
Department of Environmental Health
Kuopio, FINLAND

Ongoing European activities

Project	Health effects	Exposures	Sources
HITEA	respiratory diseases	microbes, $PM_{2.5}$, NO_x microbial toxins	moisture damage, dampness, mould
EnVIE	asthma, respiratory allergies and infections, lung cancer, COPD, CV mortality, sensory irritation	[combustion] PM, CO, Rn, bioaerosols, VOCs	outdoor air & soil, building materials/equipment/ventilation consumer products, occupant activities
Heimtsa-IAQ	Respiratory cancers, asthma, CV mortality	Rn, naphthalene, formaldehyde, ETS	soil, dampness, heating & cooking, smoking
IAQ expert group			soil, building materials, ventilation, heating, cooking, cleaning
IndEx		NO_2, CO, PM, naphthalene, form-aldehyde, benzene,	
IAQ Guidelines		Group A:24 agents Group B:biologicals	Group C: solid fuel use
Inadequate housing and health	asthma, COPD, respiratory infections, tuberculosis	formaldehyde, ETS CO, PM, Pb, noise	dampness, mould, crowding, solid fuel use, traffic

European indoor exposure data

- National surveys:
  - German Environmental Survey (GerES I…IV), 1985-2006
  - French IAQ Observatory (OQAI), 2003-05
- EU Projects:
  - EC FP-3, Audit study, 1993-94
  - EC FP-4, EXPOLIS, 1996-98
  - EC/JRC, Macbeth,1998; People, 2002-04; AirMex, 2003-07
- EU Data surveys:
  - DG-SANCO: THADE, 2002-03
  - DG-SANCO/JRC: IndEx, 2002-04
  - EC FP-5, EnVIE WP-2 (Exposure), 2004 -08
  - JRC: Radon mapping (EUR RADON 2005)

European IAQ summary

Agent	Long term (I)AQG (µg/m³)	Typical (µg/m³)	Indoor source (%)	High end (µg/m³)	Indoor source (%)
PM2.5 (PM10/2)	10	10 – 40	- 30	100 – 300	> 90
CO (*	10	1 – 4	0	100 – 200	> 99
NO_2	40	10 – 50	- 20	100 – 200	> 75
Formaldehyde	30 (**	20 – 80	> 90	200 – 800	> 99
Benzene	5	2 – 15	- 40	- 50	> 75
Naphthalene	10	1 – 3	- 30	- 1000	> 99.9
Radon (Bq/m³)(***	200	20 – 100	> 90	- 100 000	> 99.9

*) mg/m³ **) refers to short term, 30 min, peak concentrations ***) main source is the soil beneath the building

For 4 out of these 7 indoor contaminants a large proportion of indoor air exposure concentrations exceed the WHO as well as IndEx proposed guidelines

For $PM_{2.5}$ and NO_2 indoor air levels are usually lower than outdoor air levels

For formaldehyde and radon the role of outdoor air is always marginal

For 4 out of these 7 the high end indoor air exposure concentrations – with high individual risks – originate only from indoor sources

Radon

Long term IAQG value for radon in buildings is 200 Bq/m^3 in most EU countries

Outdoor air radon levels are low, typically below 10 Bq/m^3

Indoor levels may be several orders of magnitude higher, and also exceed the IAQG by a factor of 100

Country	AM Bq/m^3	Population 'dose' M#*Bq/m^3	GM Bq/m^3	GSD	Percent. >200 Bq/m^3	Percent. >400 Bq/m^3	Max obs Bq/m^3
Albania	120	408	105	2.0			270
Austria	97	795	61		12.0	4.0	8 325
Belgium	69	718	76	2.0		0.5	4 500
Bulgaria	30	255	22				250
Croatia	68	306			7.2	1.8	751
Cyprus	7	6	7	2.6			78
CzechRep	140	1428	110		15.0	2.5	25 000
Denmark	53	292	64	2.2	2.9	0.2	590
Estonia	120	180	92				1 390
Finland	120	624	84	2.1	12.3	3.6	33 000
France	89	5536	53	2.7	8.5	2.0	4 964
Germany	50	4120	40	1.9	3.0	1.0	10 000
Greece	55	594	44		3.1	1.1	1 700
Hungary	107	1081	82	2.7			1 990
Ireland	89	374	57		7.5	1.5	1 924
Italy	70	4060	52	2.0	4.1	0.9	1 036
Latvia							
Lithuania	55	204	22				1 860
Luxembourg	115	58		2.0		3.0	2 776
Malta							
Netherlands	30	498	25	1.6	0.3	0.0	382
Norway	89	409			9.0	3.0	50 000
Poland	49	1887		2.0	2.0	0.4	3 261
Portugal	86	920	39	2.2			3 558
Romania	45	1022					1 025
Slovakia	87	470					3 750
Slovenia	87	174			7.7	2.0	1 890
Spain	90	3645	45	3.7	6.0	2.0	15 400
Sweden	108	972	56		11.0	3.5	3 904
Switzerland	77	585			17.0	7.0	29 705
UK	20	1220			0.5	0.1	17 000

Highest risk indoor air chemicals

- Five assessments prioritised indoor air chemicals according to health risks at existing concentrations
- All ended up with the same priority chemicals

STUDY	**I** Benzene	**II** Naphthalene	**III** Formaldeh.	**IV** Acetaldeh.	**V** Hexane
De Hollander et al. 1999 (1	■				
Loh & Bennet, IA 2005 (2	■	■	■		
JRC, IndEx, 2005 (3	■	■	■		
Jantunen, HB-2006	■	■	■		■
Levin et al. HB-2006	■	■	■	■	■

1) Assessed and ranked 13 major environmental health risks

2) Not restricted to indoor sources, therefore included also 1,3 butadiene

3) Not restricted to organic chemicals, therefore included also NO_2 and CO

ETS and micro-organisms

- For both quantitative agent/species specific exposure data are scarce, but abundant on a qualitative level
- “does anyone smoke in the household?”
- “do you see wet spots or visible mould on any surfaces inside your home?”
- Health effects for both are well established, but also based on “YES/NO” data.
- Also risk management relies on YES/NO actions.

EnVIE – Risks – Exposures - Sources

What makes EnVIE different

- Most studies have focused on the measurement and modelling of the **exposures to and risks of chemical, physical and biological agents** in the indoor air of specific buildings, or buildings representing a city or country (GerES and [F]OQAI).
- The focus of EnVIE was to assess the European level **public health benefits of different IAQ policies**.

The EnVIE Concept: from health impacts to policies

2. Exposures

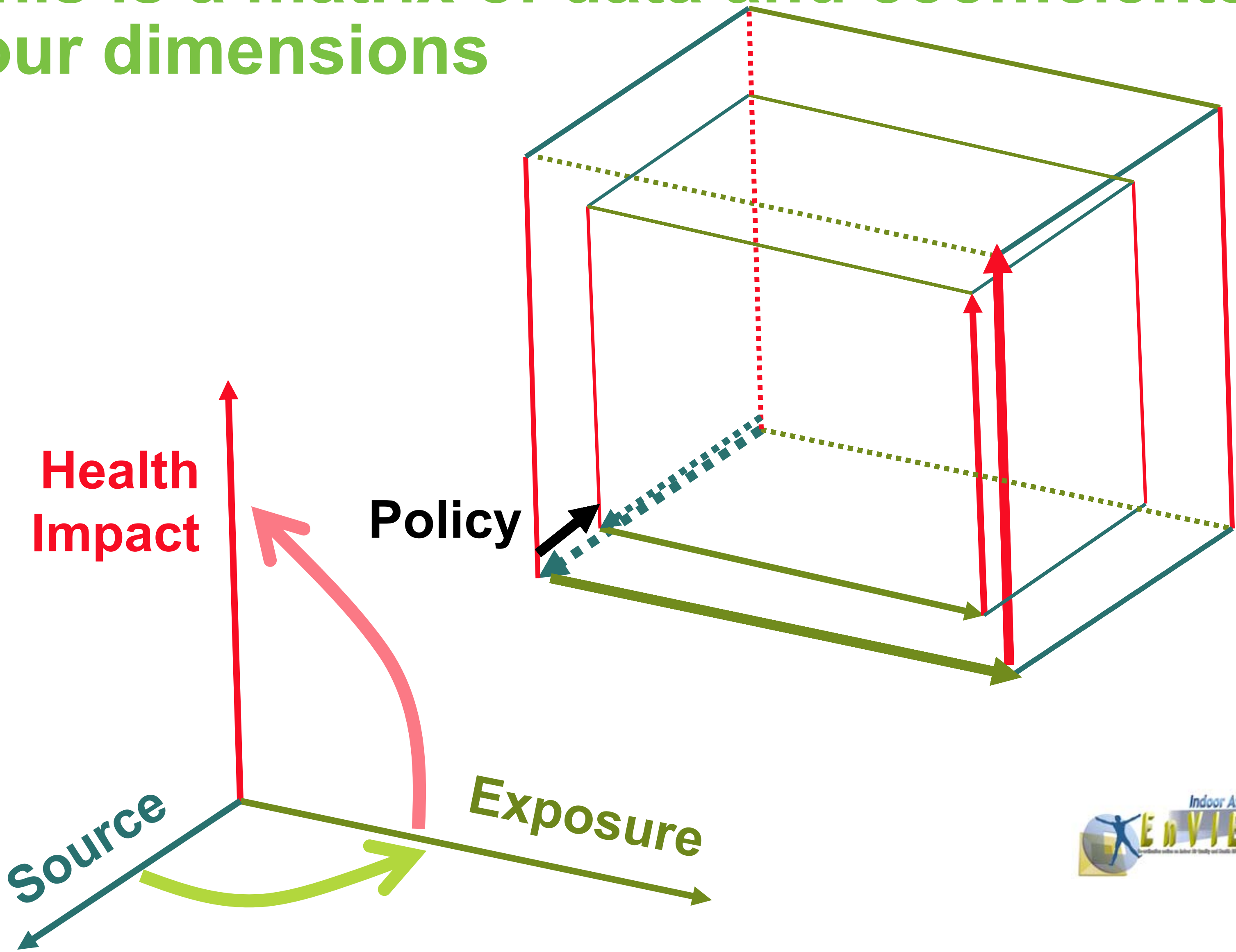
1. Health impacts

1. Health impacts	Tobacco	Combustion particles	CO	Radon	Moisture, molds, dust mites	(S)VOCs
Allergy & asthma symptoms	•	•			•	•
Lung cancer	•	•		•		
Obstructive pulmonary lung disease	•	•			•	
Airborne respiratory infections	•	•			•	
Cardiac morbidity and mortality	•	•	•			
Sick building syndrome, irritation	•	•			•	•

3. Sources → **4. Policies**

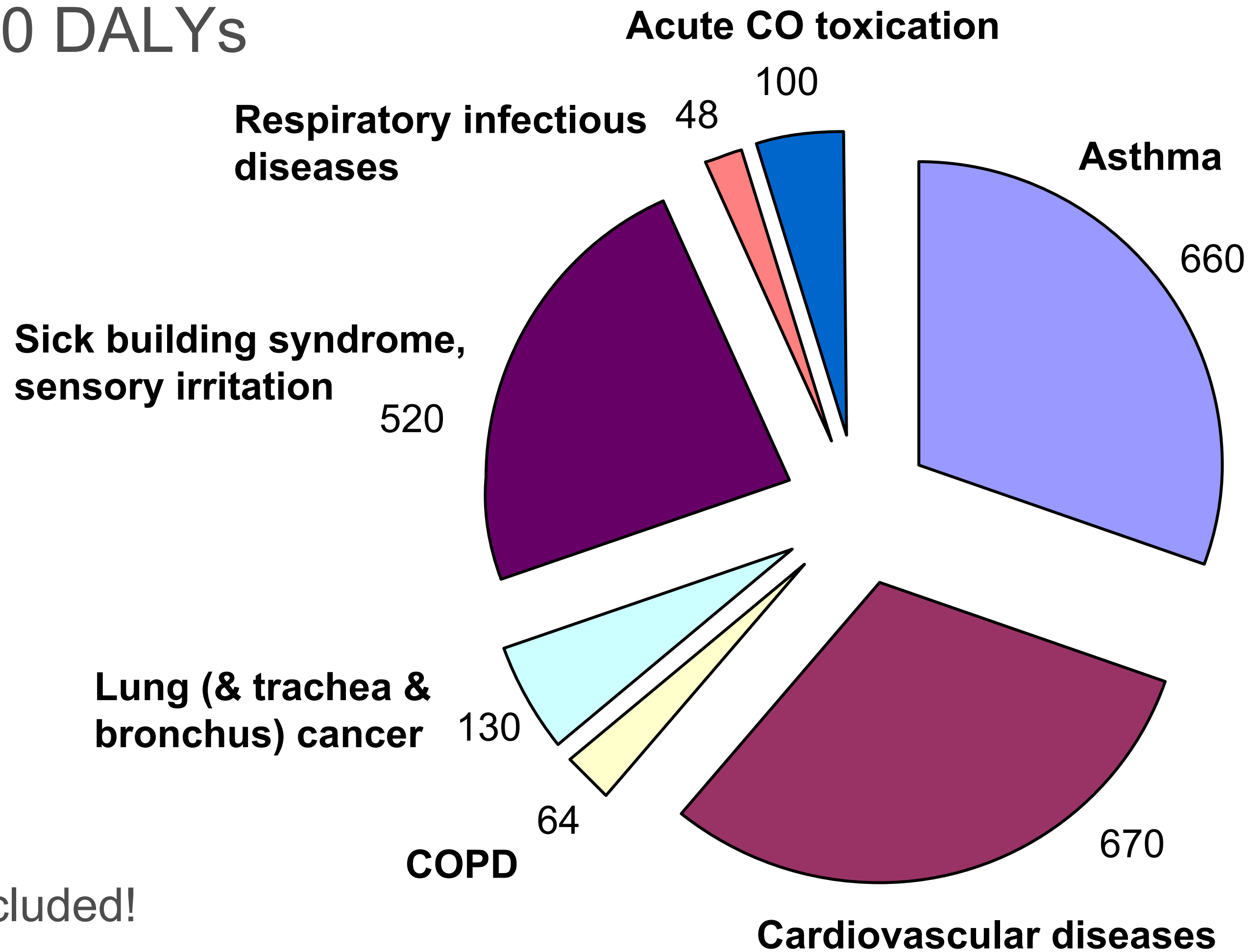
3. Sources	Tobacco	Combustion particles	CO	Radon	Moisture, molds, dust mites	(S)VOCs
Outdoor air		•	•		•	•
Building/Equipment/Ventilation	•	•	•	•	•	•
Consumer products		•				•
Occupant behaviour & maintenance	•	•	•	•	•	•

This is a matrix of data and coefficients in four dimensions



BoD by disease caused by indoor air contaminants in EU-27. 2.2 million DALY/y!

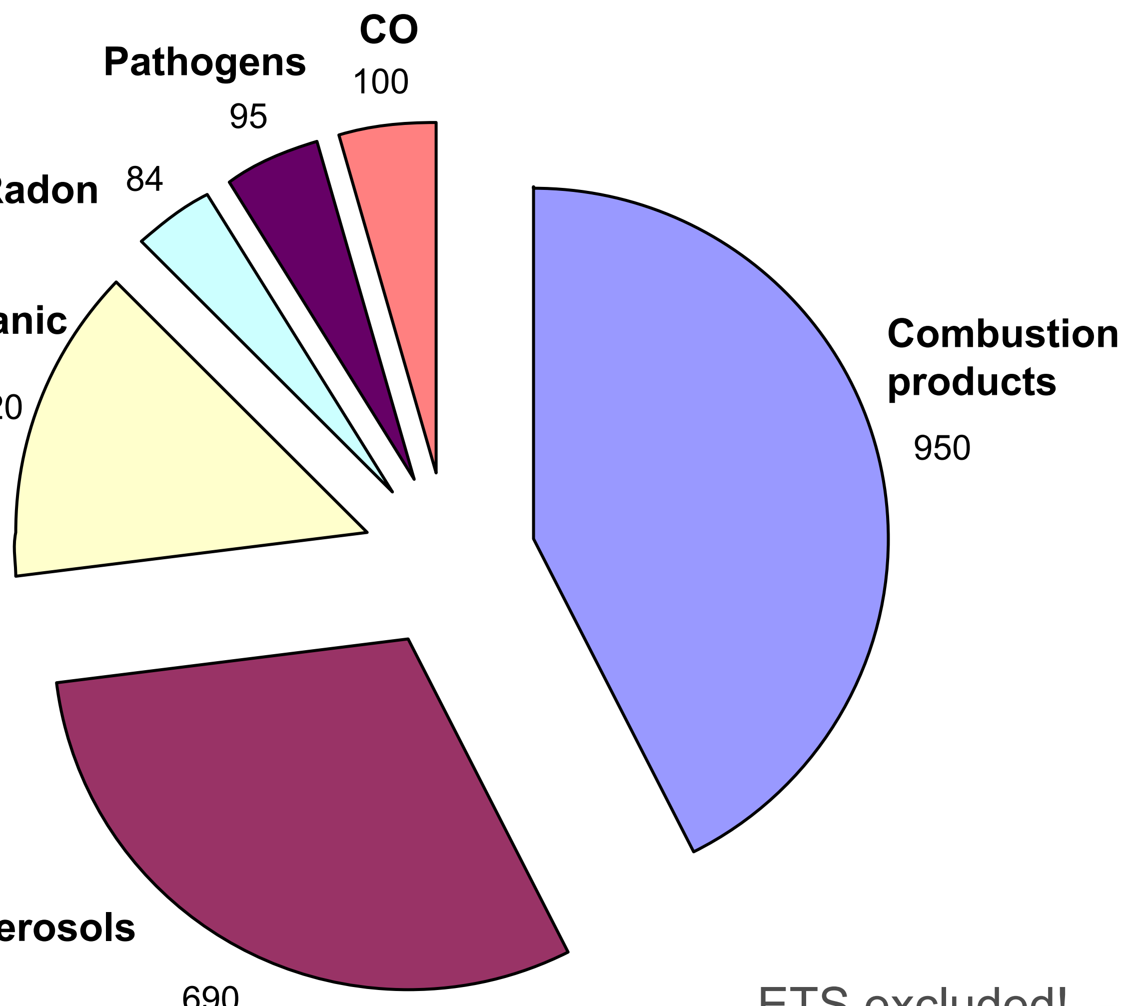
By disease/symptom
in 1000 DALYs



ETS excluded!

BoD by exposure to indoor air contaminants in EU-27

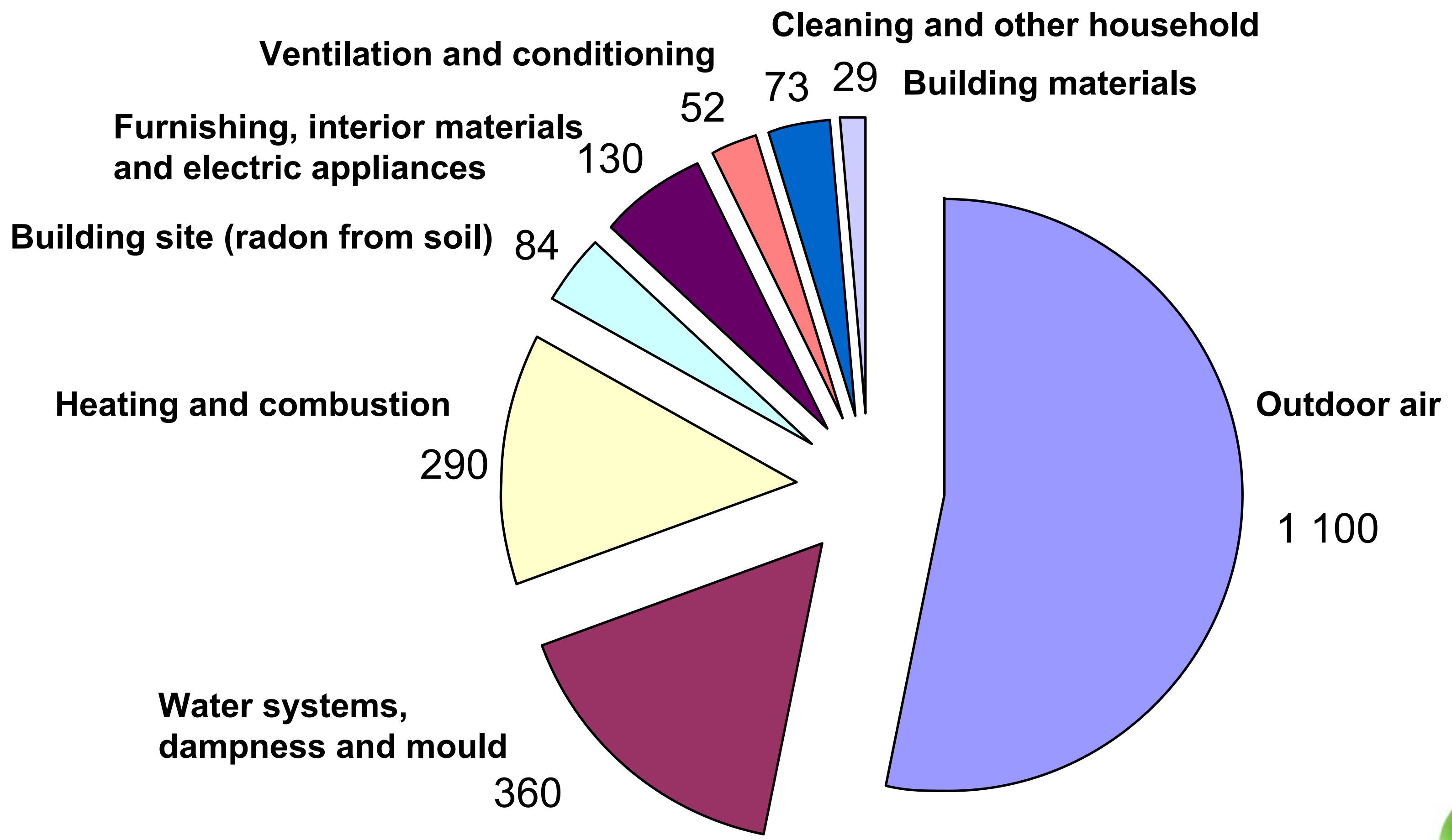
By causal agent
in 1000 DALYs



ETS excluded!

BoD by source of indoor air contaminants in EU-27

By source in 1000 DALYs



ETS excluded!

Tobacco?!

- Where smoking still goes unrestricted, ETS is comparable to all other indoor air pollution combined
- In increasing number of countries smoking has already been banned in
  - workplaces - schools,
  - public transportation, - restaurants
  - most other public spaces

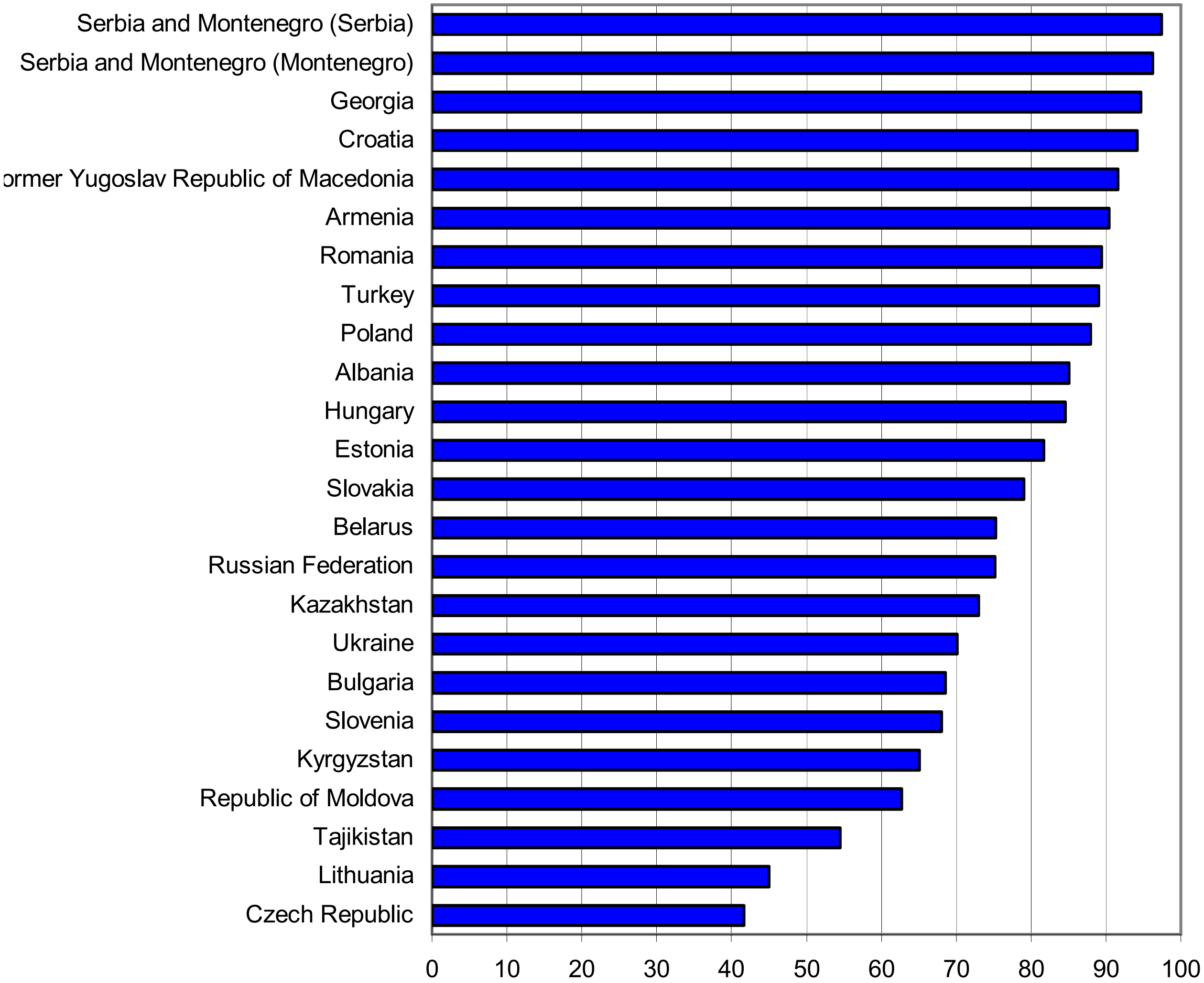
  i.e. ETS exposure is increasingly restricted to spouses and children of smokers in private residences

Tobacco?!

- The uncomfortable fact is that **children of the most deprived families have the lowest level of protection** and suffer from the highest exposures
- This is <u>the</u> most glaring IAQ inequity issue, a complex societal challenge that should be dealt with

Children's exposure to ETS (%)

WHO/ENHIS Factsheet



Conclusions – exposure and risk

- At population level only 3-5 chemicals, benzene, formaldehyde and naphthalene, are responsible for most of the indoor air chemical risks.
- All chemicals combined are responsible for only 8-20% of all indoor air health risks.
- Most of the indoor air health risks are caused by
  - tobacco smoke - where still allowed,
  - outdoor air pollutants which penetrate into indoor air,
  - indoor combustion sources,
  - building dampness and mould

WHO IAQ Guidelines will – again - be a valuable source of information for risk identification and management

EnVIE – Europe wide IAQ policies

Indoor [related] European policies

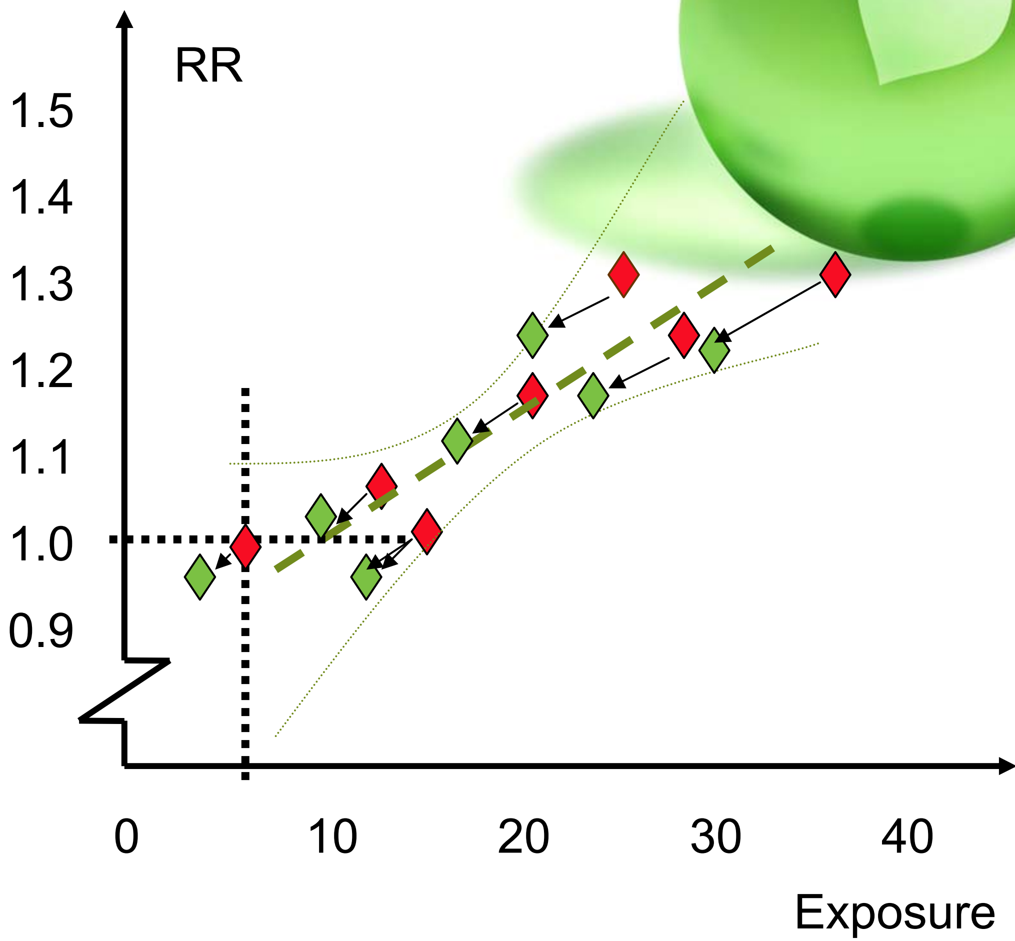
- EU:
  - Construction Products Directive (CPD), 89/106/EEC EC
  - General Product Safety Directive (GPSD), 2001/95/EC
  - Energy Performance of Buildings Directive (EPBD), 2002/91/EC
  - Regulation concerning Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), 1907/2006

- WHO:
  - WHO Framework Convention on Tobacco Control, WHO FCTC, 2005 and related EC Green Paper: Towards a Europe free from tobacco smoke: policy options at EU level, COM (2007)27
  - IAQ Guidelines update is under development (Dampness & Mould available in 2009)

The policy orientation is usually action (measurement, reporting, restriction)

not result (health improvement)

Policy assessments



For most agents there is an exposure level, below which health effects are non-measurable.

→ The assumption that reducing the exposure will reduce the attributable risk in proportion to the exposure all the way to zero is non-testable.

We assume, instead, that reducing the exposure by 10% the attributable risk is reduced by 10%.

→ This assumption is testable and realistic.

Most policies have gradual and relative, rather than absolute impacts on the

Policies to reduce penetration of outdoor air and soil pollution into indoor air by 10%

- In EU-27 the estimated risk reduction potential([1,2] of keeping indoor air cleaner of outdoor pollution – applying 10% of the maximum potential → **89 000 DALY/y**

- … applying 10% of the maximum potential of radon safe construction → **8 400 DALY/y**

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1) Requires implementation through the building stock over a long time
2) Impacts of other reduction levels can be scaled from these values

Policies to improve pollution control by HVAC systems and control of moisture by 10%

- A perfect ventilation system controls indoor air contaminants from both indoor and outdoor sources. In EU-27 10% the maximum estimated risk reduction potential → **66 000 DALY/y**
- 1/3 of this benefit could be achieved by a regular inspection and maintenance programme → **23 000 DALY/y**
- Prevention of dampness and mould by applying appropriate guidelines for building construction and maintenance in 10% of the buildings could reduce associated risks → **26 000 DALY/y**
- Providing 10% of kitchens, bath and laundry rooms with waterproof surfaces and humidity controlled extract ventilation → **17 000 DALY/y**
- Specifically, ensuring self drying building structures and materials → **15 000 DALY/y**
- Mandating regular inspections for all indoor combustion equipment and banning all unflued systems … 10% → **15 000 DALY/y**

Policies to improve pollution control via general building and construction management by 10%

- Integrating IAQ requirements into EPBD procedures could reduce indoor air contaminants from most indoor and outdoor sources. In EU-27 10% of the estimated risk reduction potential is → **96 000 DALY/y**
- Systematic operation, inspection and maintenance documentation for 10% of buildings and installations with responsible and qualified building managers → **49 000 DALY/y**
- European harmonised testing and labelling of all building materials, equipment and products…10% → **30 000 DALY/y**

The beneficial impacts of these general building policies exhibit large uncertainties depending on how they are interpreted and implemented. Probable benefits are smaller, except for the testing and labelling scheme.

Qualifiers

- **Time and cost:** Some policies can be implemented quickly and cheaply, while others require decades and are very expensive – except when implemented along normal renewal and renovation schedules. Policies which provide only marginal health benefit may still be quite cost effective.
- **Invasiveness:** Some policies affect only certain product manufacturers, while others set requirements on every citizen
- **Interdependence:** Estimated policy benefits cannot be summed because they – more or less – overlap, depend on and sometimes even contradict each other
- **Individual vs. population:** The current assessment focuses solely on Europe wide public health issues. Policies that appear marginal for public health may be critical for individual risks – and *vice versa*

Conclusions - policies

- Highest public health benefits at lowest cost and smallest delay can be achieved by **smoking restrictions**.
- High long term benefits at high cost can be achieved by **building and ventilation** policies, which control indoor exposure to PM, allergens, O_3, and Rn (and noise) from outdoor environment.
- Substantial medium term benefits can be expected at medium cost from policies that ensure better building **documentation, management, inspection, task assignment and training** of the responsible individuals
- Substantial medium to long term benefits at costs ranging from low to high can also be expected from policies to
  - prevent **moisture accumulation** and, thus, mould growth in buildings and
  - prevent exposure to exhausts of indoor **combustion sources.**
- Substantial short to medium term benefits at low cost can be expected from **harmonised testing and labelling** of indoor materials and consumer products.

HEIMTSA Indoor Air Case Study

What new will that bring along?

- HEIMTSA IAQ Case Study will dig much deeper than EnVIE on a few *specific agents* and *spatial distribution*, instead of general categories like *VOCs* or *combustion products*, but
- … will also assess the impacts of policy scenarios on health
- … will also aim at European coverage

HEIMTSA

Selection of exposure agents

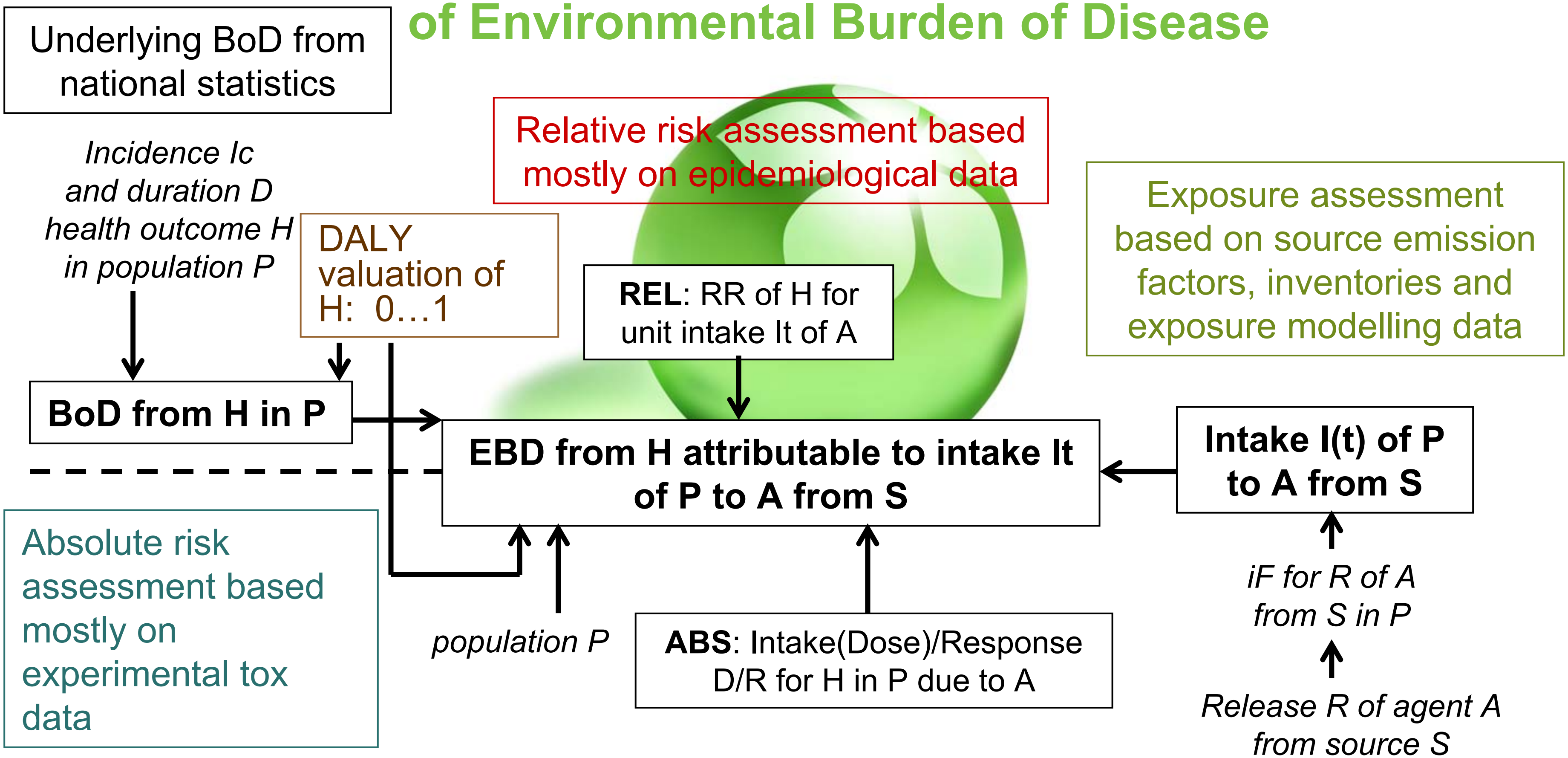
	IndEx	EnVIE		HEIMTSA
Organic chemicals:				
– benzene	X	X	VOCs	
– naphthalene	X	X	VOCs	X
– formaldehyde	X	X	VOCs	X
Inorganic chemicals:				
– NO_2	X	X		
– CO	X	X		
Other:				
– ETS		X		X
– radon		X		
– micro-organisms.		X		

Ambition levels

HEIMTSA

- **General:**
  - 1st: platform for the assessment of policy impacts, exposure/risk reduction or increase (ignoring background)
  - 2nd: assessment of policy impact relative to current state/exposure/effect (need background)
- **Spatial:**
  - 1st: European cities with sufficient data
  - 2nd: European regions (e.g. using scaling factors for most representative available *iF* data) / EU-Europe
- **µenvironments:**
  - 1st: Residences, day care centres, schools, offices
  - 2nd: All indoor environments
- **Exposure/intake:**
  - 1st: Ambient pollution levels as proxy for indoor and exposure
  - 2nd: Indoor intake from indoor sources using *iF* data
- **Risk:**
  - 1st: Linear no-threshold D/R slope applicable for small changes
  - 2nd: Best available D/R models
- **Temporal:**
  - 1st: Apply 24h – 1 wk existing data as such
  - 2nd: Estimate annual exposure and lifetime risk
  - 3rd: Estimate lifetime exposure (incl. residential and occupational tenures) for lifetime risks
- **Population:**
  - 1st: Urban/regional/national level
  - 2nd: Distribution of individual levels

Relative and absolute risk models for assessment of Environmental Burden of Disease



Terms and units:

Ic= incidence ($\#_{cases}/(\#_{exposed}$ *time))

H= health outcome (e.g. ICD)

P= exposed population (#)

S= source/source category

RR= relative risk

iF= intake fraction (I(t)/R)

D= duration (time)

I(t)= intake (mass/time)

A= agent (e.g. CAS#)

R(t)= release (mass/time)

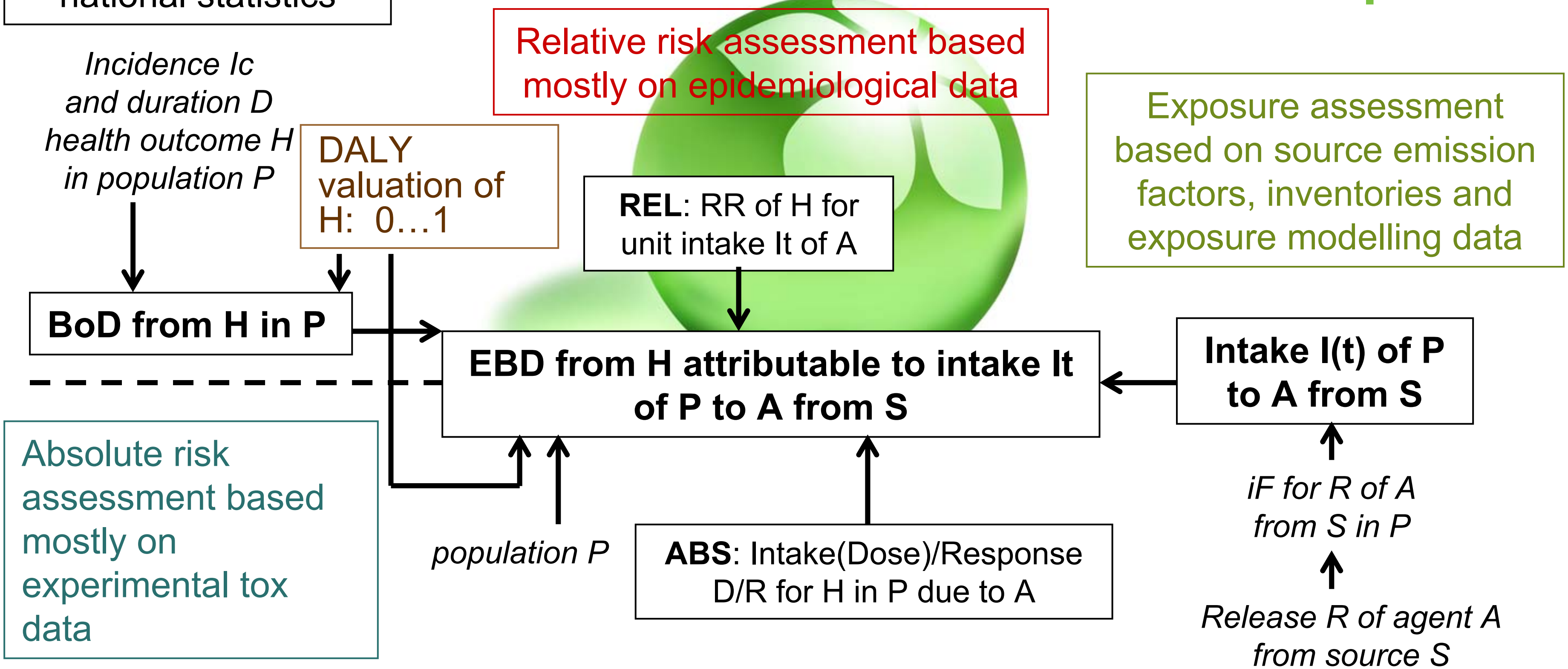
D/R = intake-response

HEIMTSA

Thank you –

questions, comments, riots?

Relative and absolute risk models for assessment of EBD from different exposures



Terms and units:

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RR= relative risk

iF= intake fraction (I(t)/R)

D= duration (time)

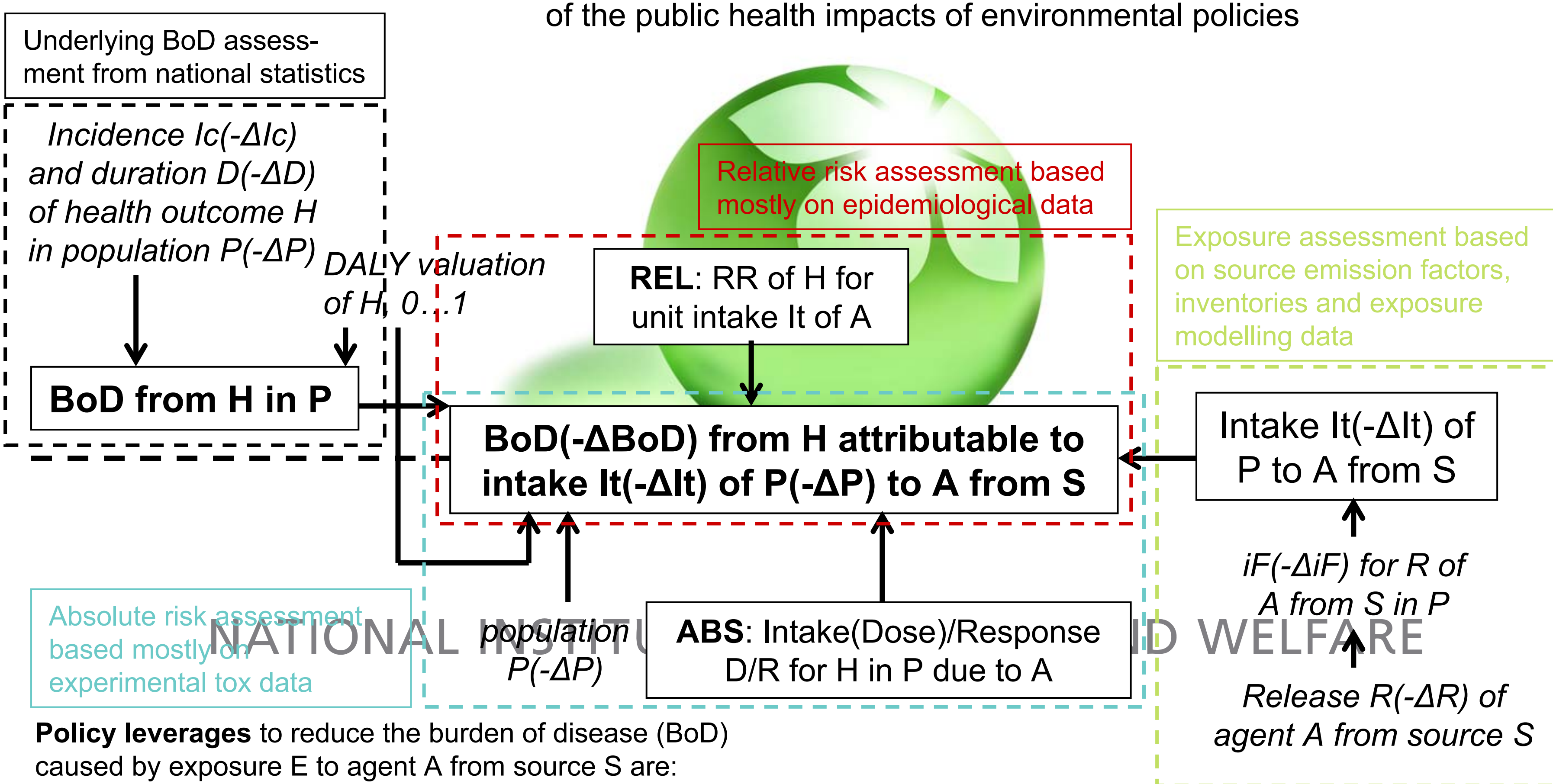
I(t)= intake (mass/time)

A= agent (e.g. CAS#)

R(t)= release (mass/time)

D/R = intake-response

Combination of the relative and absolute risk models for the assessment of the public health impacts of environmental policies



Policy leverages to reduce the burden of disease (BoD) caused by exposure E to agent A from source S are:

- To reduce the intake from It to It-ΔIt either by reducing (or eliminating) the release from R to R-ΔR (Emission control) and/or the intake fraction from iF to iF-ΔiF (pathway control)

- To reduce the exposed population from P to P-ΔP (e.g. relocating the source) and/or disease/symptom duration fromD to D-ΔD (e.g. new cure)

- To reduce the D/R due to exposure agent A in the population (e.g. immunisation, desensitisation, medication)

Terms and units:

Ic= incidence (#$_{cases}$/(# $_{exposed}$ *time))	iF= intake fraction (It/R)
H= health outcome (e.g. ICD)	D= duration (time)
P= exposed population (#)	It= intake (mass/time)
S= source/source category	A= agent (e.g. CAS#)
	R= release (mass/time)

RR= relative risk ((Ic+ΔIc)/Ic per unit increase of It)

D/R = intake-response (ΔIc/ΔIt at background It per unit P)

Two alternative/complementary Europe-wide risk and policy assessment methods

- iF-method is based on known distributions of the population intake fractions of air emissions from indoor sources and dose-response relationships of the agents
- EnVIE method is based on expert judged baseline contributions of current/past average indoor exposures from specific indoor sources to selected disease incidences and scaling of these incidences to changed or different exposures
- Most data and the valuation processes are the same for both, and I suggest that both are used.