30 Years Later: Health Effects from Chernobyl

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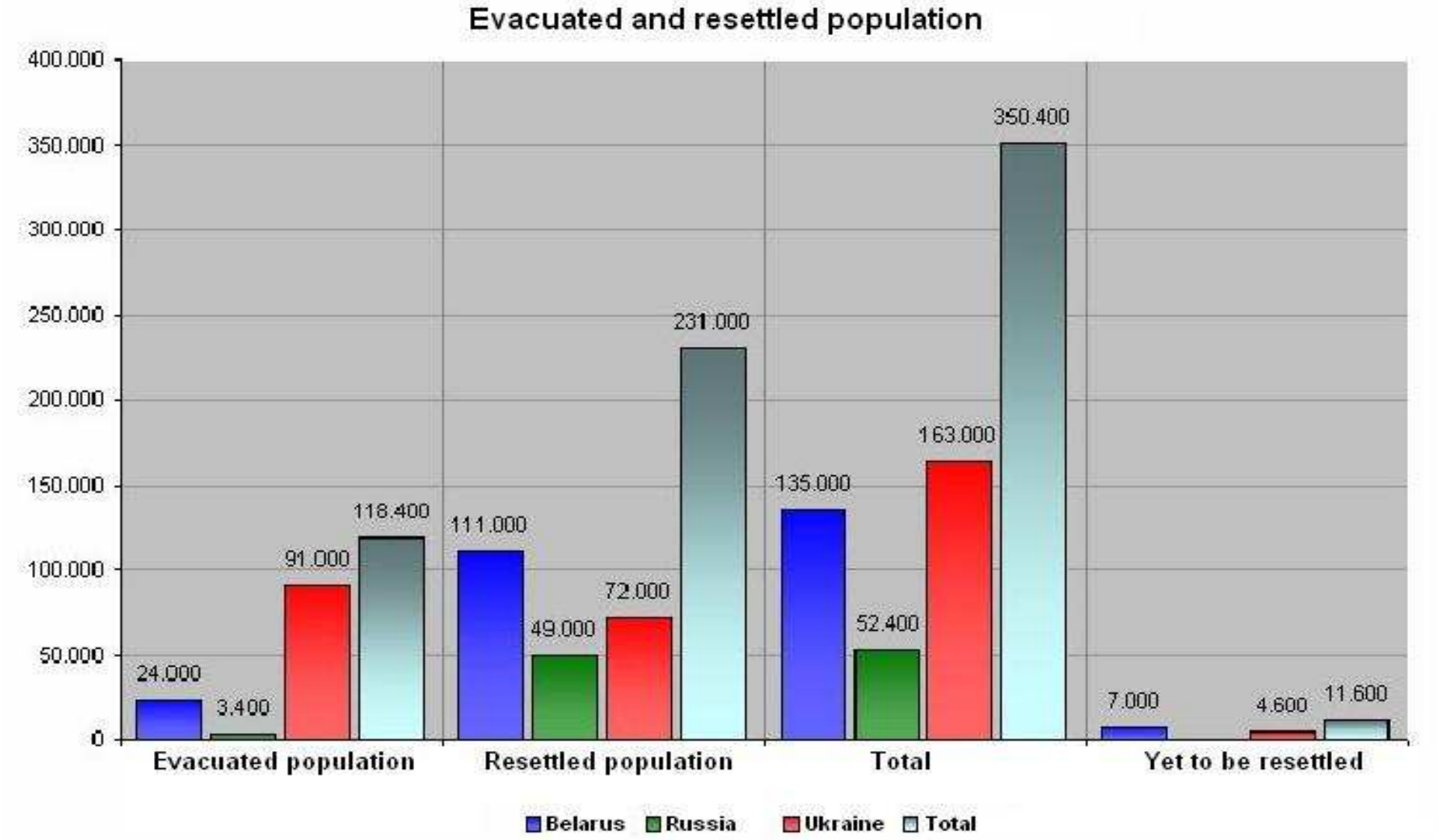
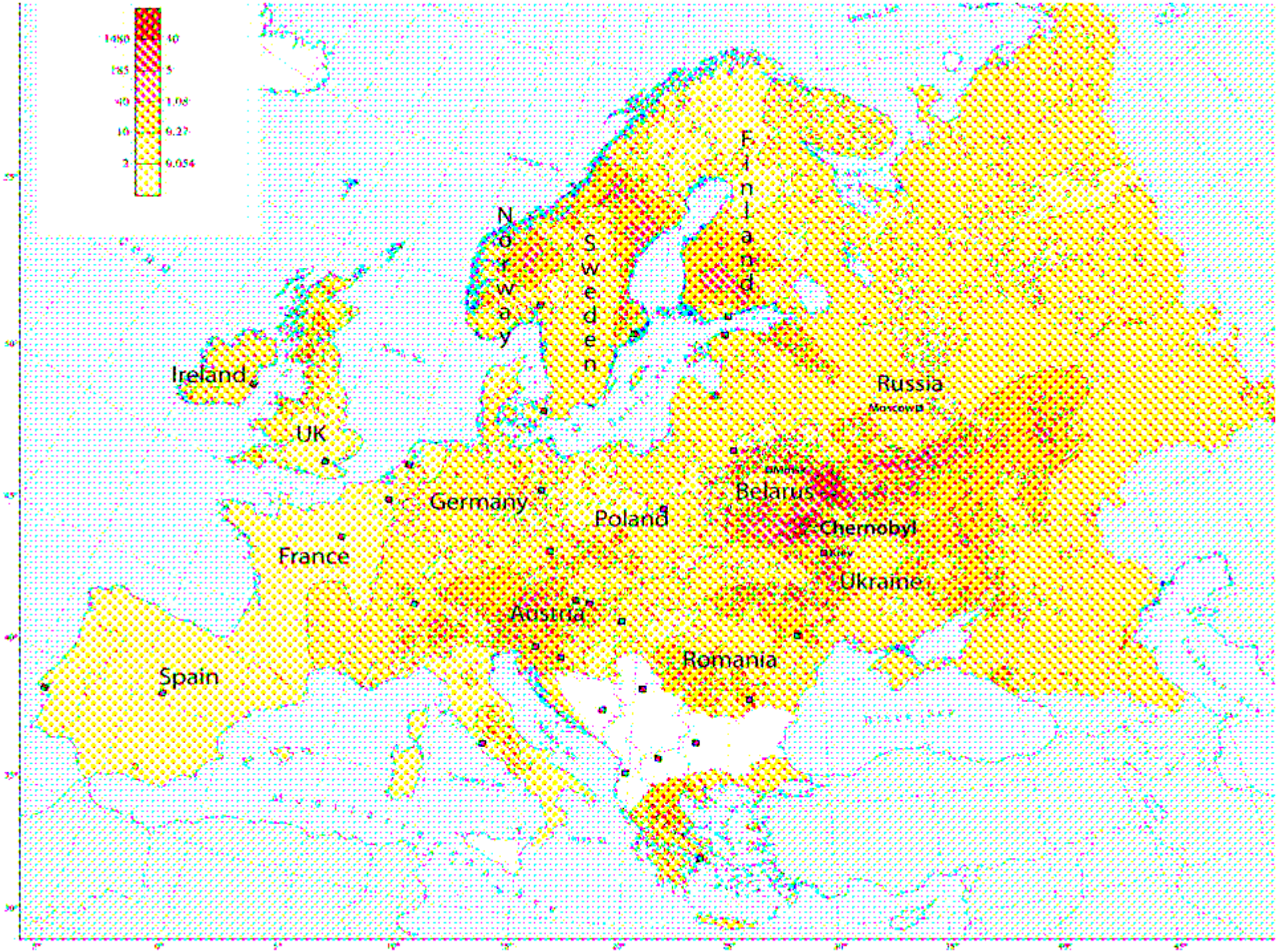
Chernobyl Accident (1986)

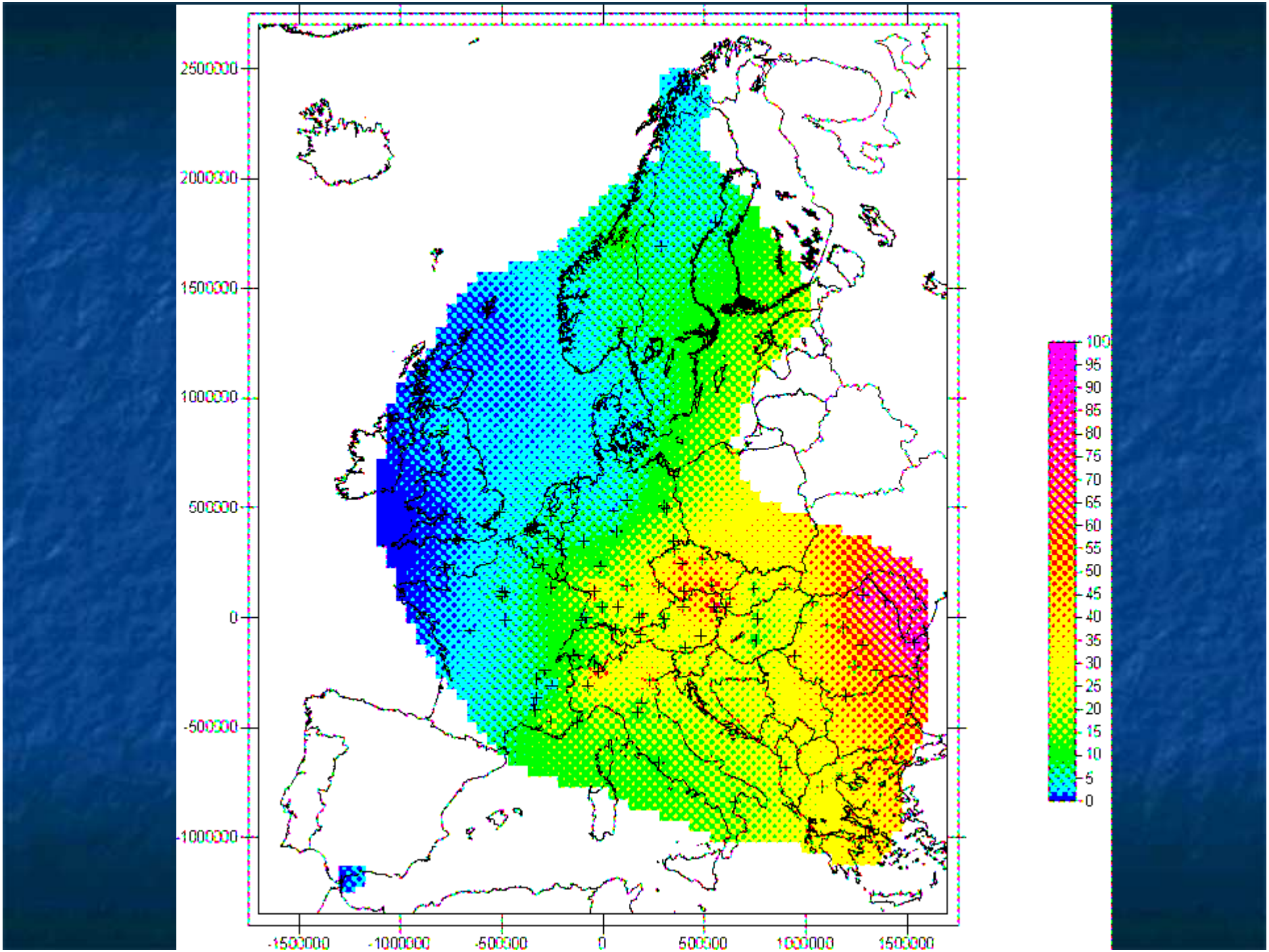
"…the foremost nuclear catastrophe in human history" IAEA (1996)

"…its magnitude and scope, the size of the affected populations, and its long-term consequences make it, by far, the worst industrial disaster on record" IAEA/WHO (2005)

Displaced Persons (UNDP 2002)




1480
185
40
10
2
40
5
1.08
0.27
0.054
Norway
Sweden
Finland
Ireland
UK
Germany
France
Spain
Poland
Belarus
Minsk
Russia
Moscow
Chernobyl
Kiev
Ukraine
Austria
Romania


2500000
2000000
1500000
1000000
500000
0
-500000
-1000000
-1500000
-1000000
-500000
0
500000
1000000
1500000
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0

Latest doses from UNSCEAR 2008

	Number	ave dose mSv	coll dose Man Sv
Recovery workers	530,000	117	62 000
Evacuees	115,000	31	3 600
Residents in contam areas of Belarus, Russia and Ukraine	6.4 million	9	58 900
Inhabitants of Belarus, Russia and Ukraine	98 million	1.3	125 000
Inhabitants of W Europe	500 million	0.3	150 000
Total			400,000

Estimated Deaths (all Europe)

	Year	Deaths
IAEA/WHO	2005	9,000
TORCH (2006)	2006	30,000 - 60,000
Cardis et al	2015	16,000 (6,700 to 38,000)
TORCH (2016)*	2016	40,000

*UNSCEAR 2008

Some of the “liquidators…”

Clean-up worker studies

DISEASE	STUDY
coronary heart	Krasnikova et al (2014)
endocrine	Kaminskiy et al (2014)
all cancers	Prysyazhnyuk et (2014)
thyroid cancer	Ostroumova et al(2014)
solid cancers	Kashcheev et al (2014)
multiple myeloma	Bazyka et al (2013)
solid cancers	Rahu et al (2013)*
leukemia	Zablotska et al (2013)
cerebrovascular	Krasnikova et al (2013)
leukemia	Ivanov et al (2012)
B-cell cancers	Gluzman et al (2011)
many diseases	Eglite et al (2009)
blood cancers	Kesminiene et al (2008)

DISEASE	STUDY
leukemia	Romanenko et al (2008)
thyroid cancer	Ivanov et al (2008)
solid cancers	Prysyazhnyuk et al (2007)
cataracts	Worgul et al (2007)
solid cancers	Ivanov et al (2007)*
cerebrovascular	Ivanov et al (2006)
B-cell cancer	Gluzman et al (2006)*
thyroid, brain	Rahu et al (2006)
solid cancers	Ivanov et al (2004)*
thyroid cancer	Ivanov et al (2003)
schizophrenia	Loganovsky et al (2000)
leukemia	Konogorov et al (1999)*
thyroid cancer	Ivanov et al (1997)

observed health effects

- thyroid cancers
- leukemias and solid cancers
- cardiovascular disease
- birth defects
- Ill health among children
- + many other effects

– see Torch (2016) in press

Epidemiology studies: care required

- differing diagnostic criteria used
- insufficient/poorly matched control groups
- small numbers – low statistical power
- confounding factors and biases
- nil or poor dose estimates

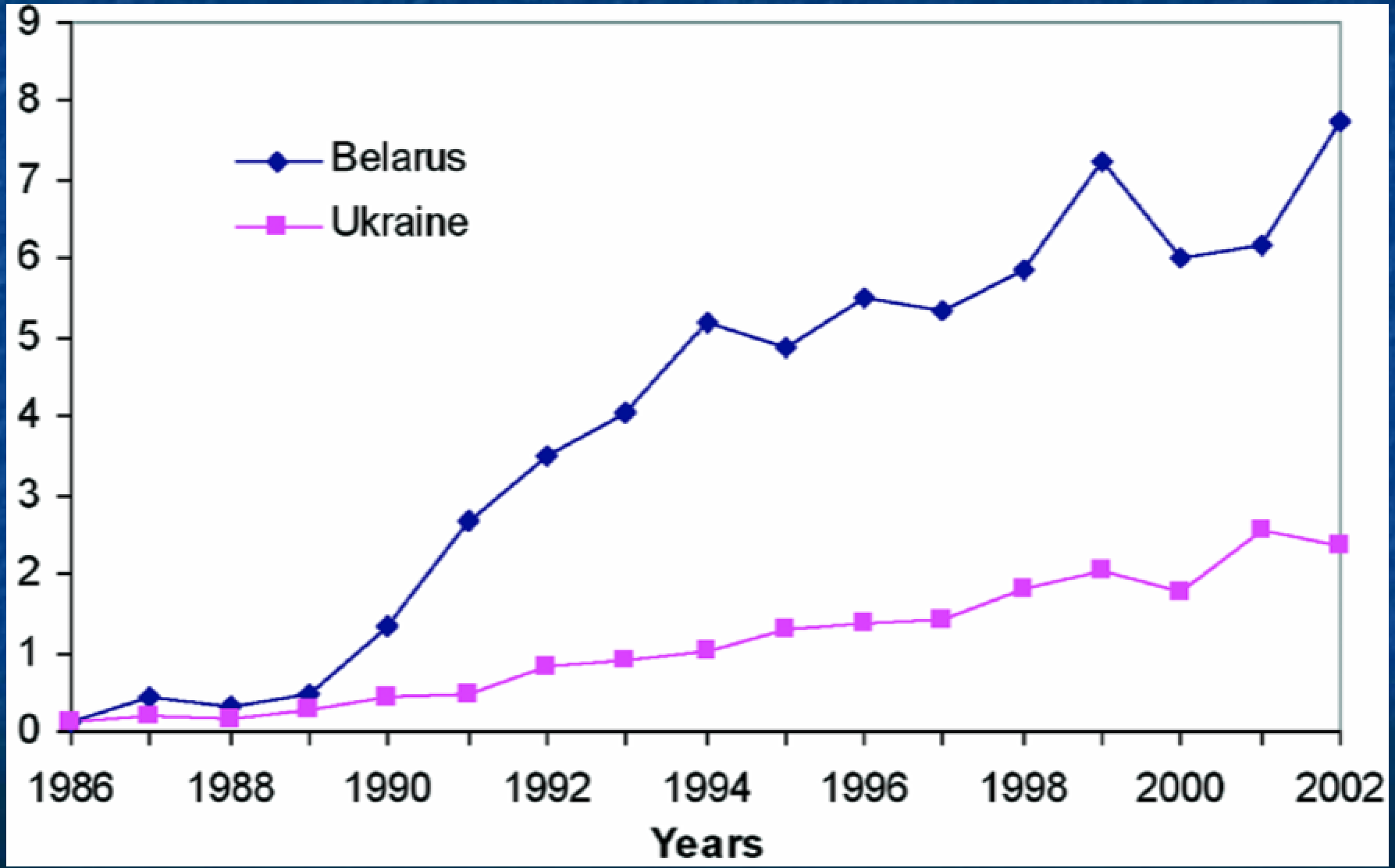
People move away, cases disappear

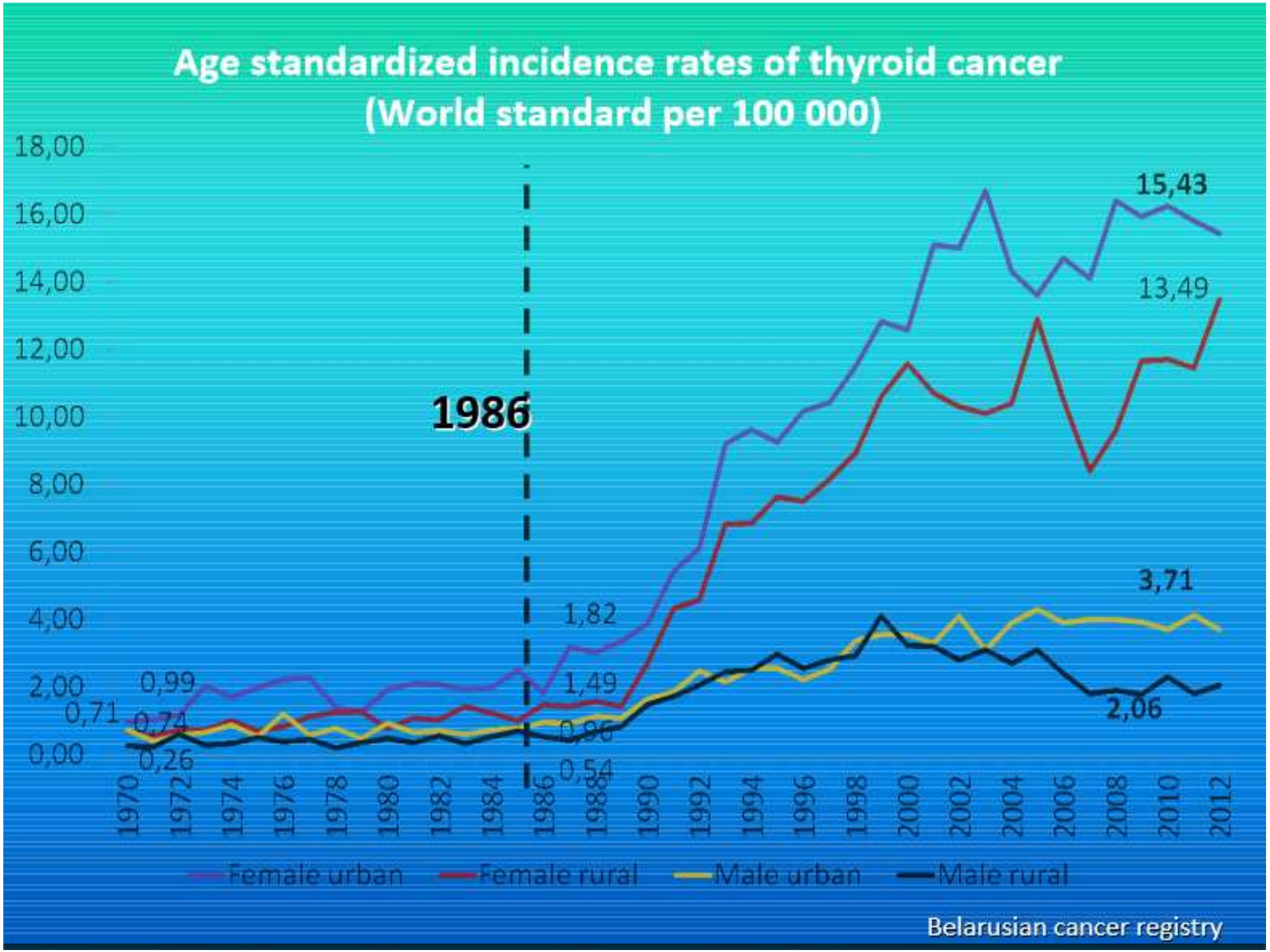
Political decisions NOT to do studies

Thyroid Cancer

Thyroid Cancer Incidence

(in those who were children and adolescents in 1986) source: Jacob *et al* (2005)

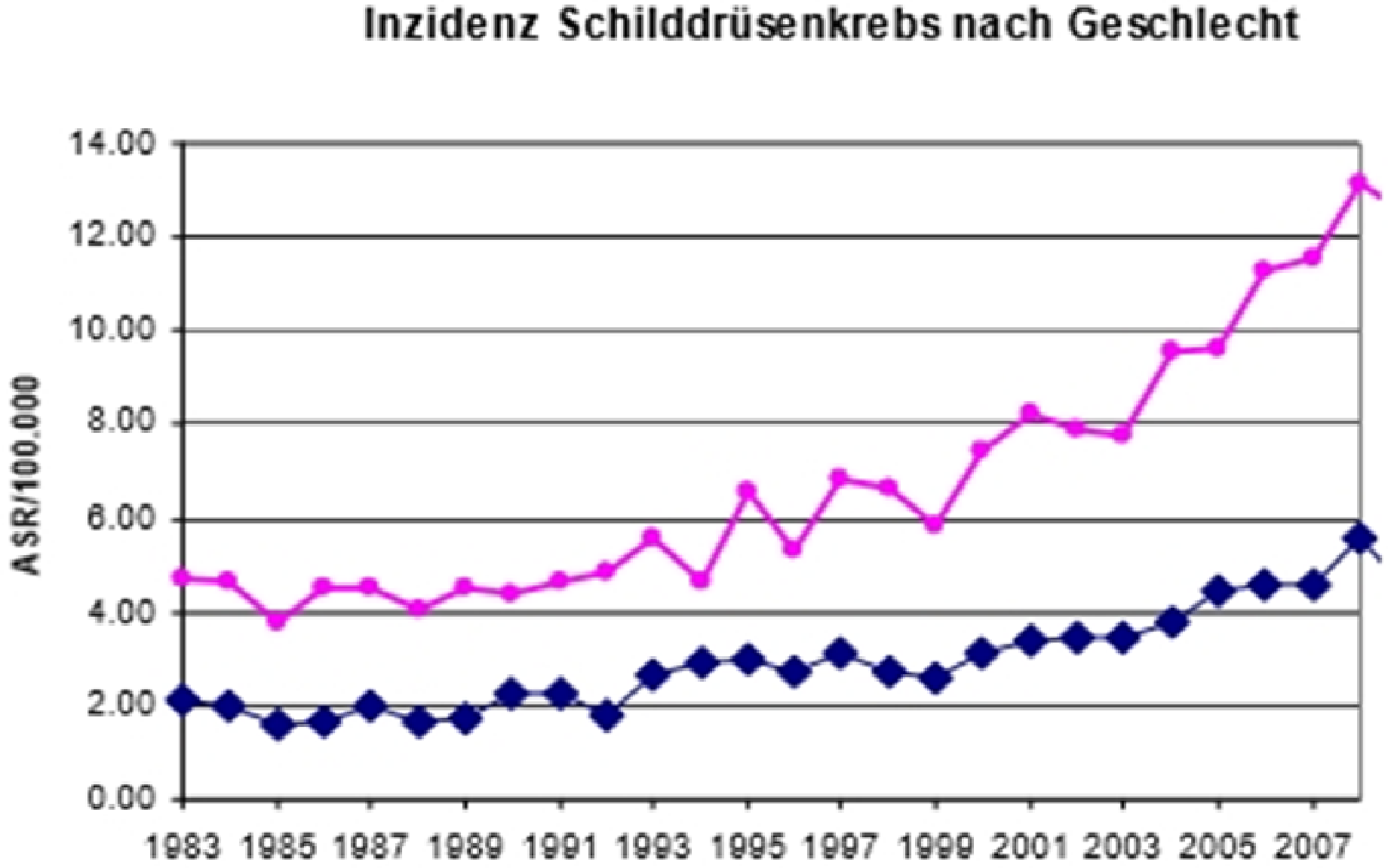



Age standardized incidence rates of thyroid cancer
(World standard per 100 000)
18,00
16,00
14,00
12,00
10,00
8,00
6,00
4,00
2,00
0,00
1986
15,43
13,49
3,71
2,06
1,82
1,49
0,99
0,74
0,71
0,26
0,54
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Female urban
Female rural
Male urban
Male rural
Belarusian cancer registry

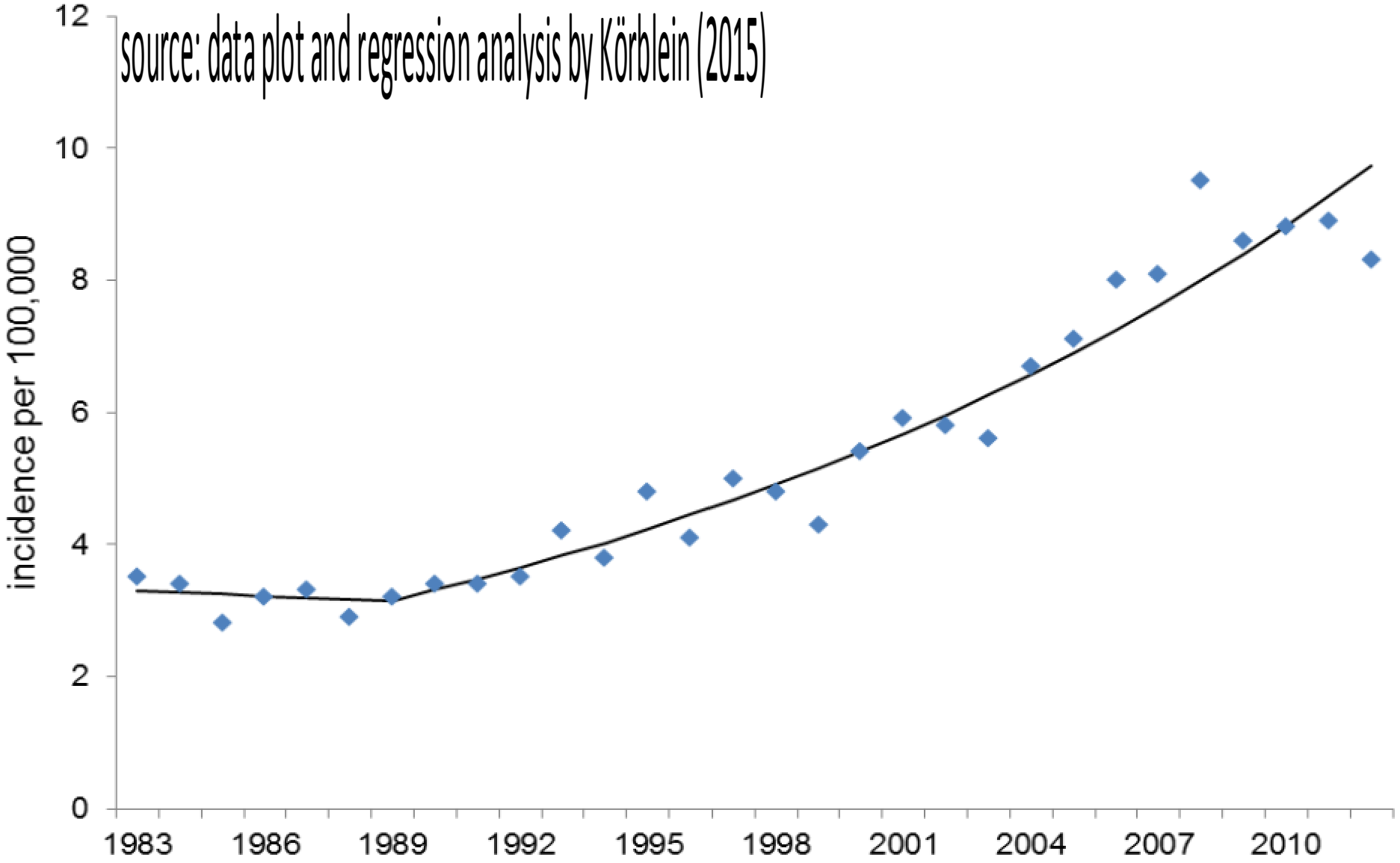
How large are thyroid cancer risks?

- estimated relative risk in the highest contam. areas are very high, ~8 (per gray)
- Ie 700% increase over background rate
- extraordinarily high, perhaps the largest increases in risk ever measured after exposures to toxic substances
- both in Ukraine and Belarus

Thyroid cancer in Austria



Thyroid Cancer in Austria



Iodine-131 in Austria

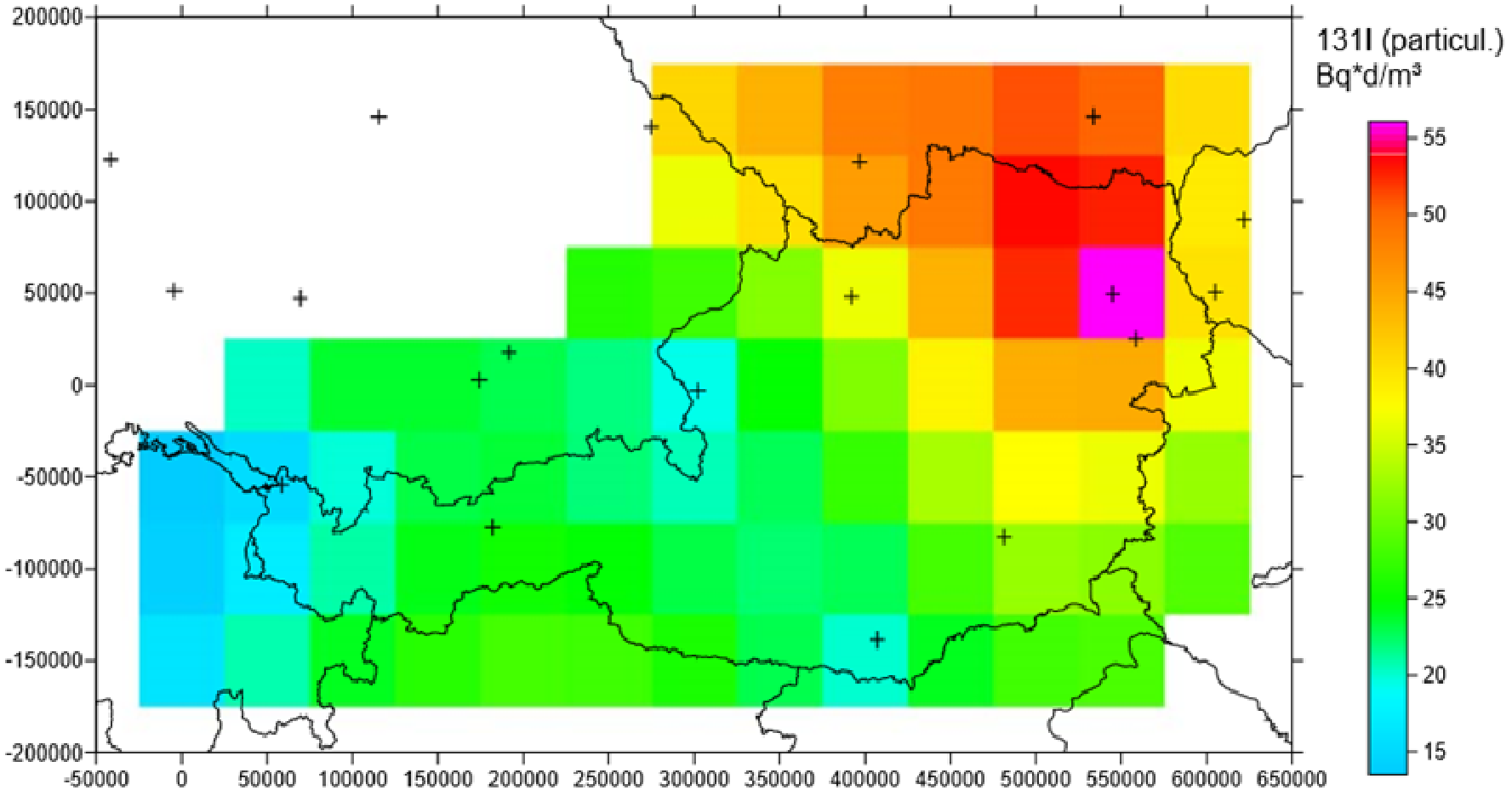


Abbildung 4: Verteilung der gemessenen kumulativen ^{131}I Aktivitätskonzentrationen (part.) in der Luft über Österreich (1986), Zellengröße: 50 × 50 km

Thyroid cancer - other countries

Czech Republic: Murbeth et al (2004) TC incidence increased by 2.6% per y (95%-CI: 1.2-4.1) after 1990

North England: Cotterill et al (2001) – incidence in children/young adults, (1987-97)/(1968-1986) = 2.3

East Slovakia: Icso et al (1998) found TC incidence was 1.3x higher in 10 yr period after Francethan before

Poland: Roszkowska and Goryński (2004) observed substantial increases in TC incidence after 1991

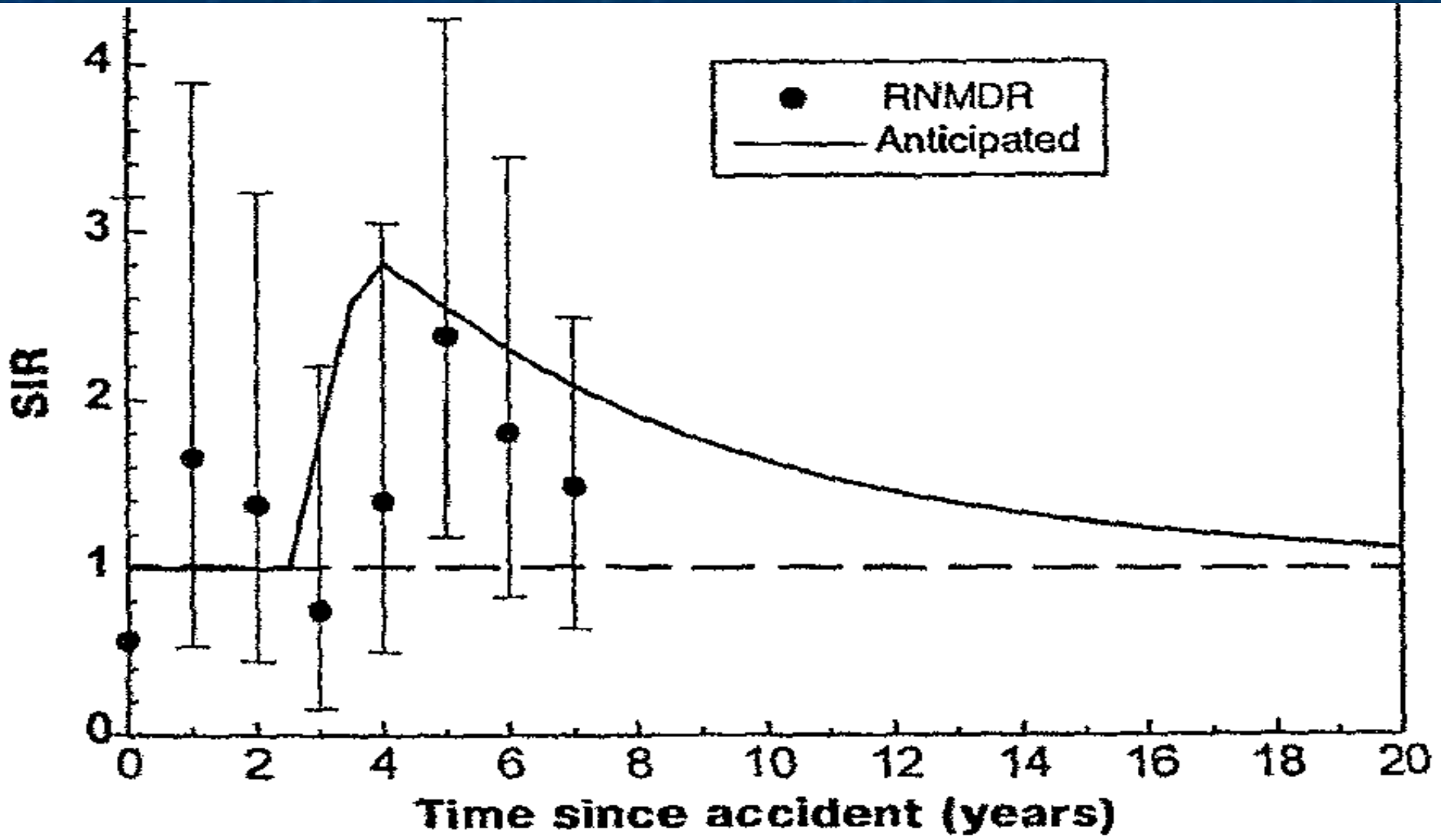
France: Verger et al (2003) reported TC incidence increased x 5.2 in men and 2.7 in women, 1975 to 1995

How many excess thyroid cancers will occur?

- So far >6,000 cases (UNSCEAR, 2008)
- >16,000 cases (Cardis, 2015)
- My own estimate is 21,000 cases

Leukemia

Leukemia in Clean-up Workers



source: Ivanov (1997)

Leukemia in Europe

- Russian workers (500% increase/Gy)
- Ukrainian workers (240% increase/Gy)
- increased incidences in Finland, Slovakia, Germany, Greece and Italy
- European Childhood Leukaemia-Lymphoma Incidence Study (IARC)
- possible *in utero* effect

Solid Cancers

increase in cancer incidence (for ages 20-85 per 100,000 population) in Belarus liquidators 1997-2000, compared with control adults in least contaminated area

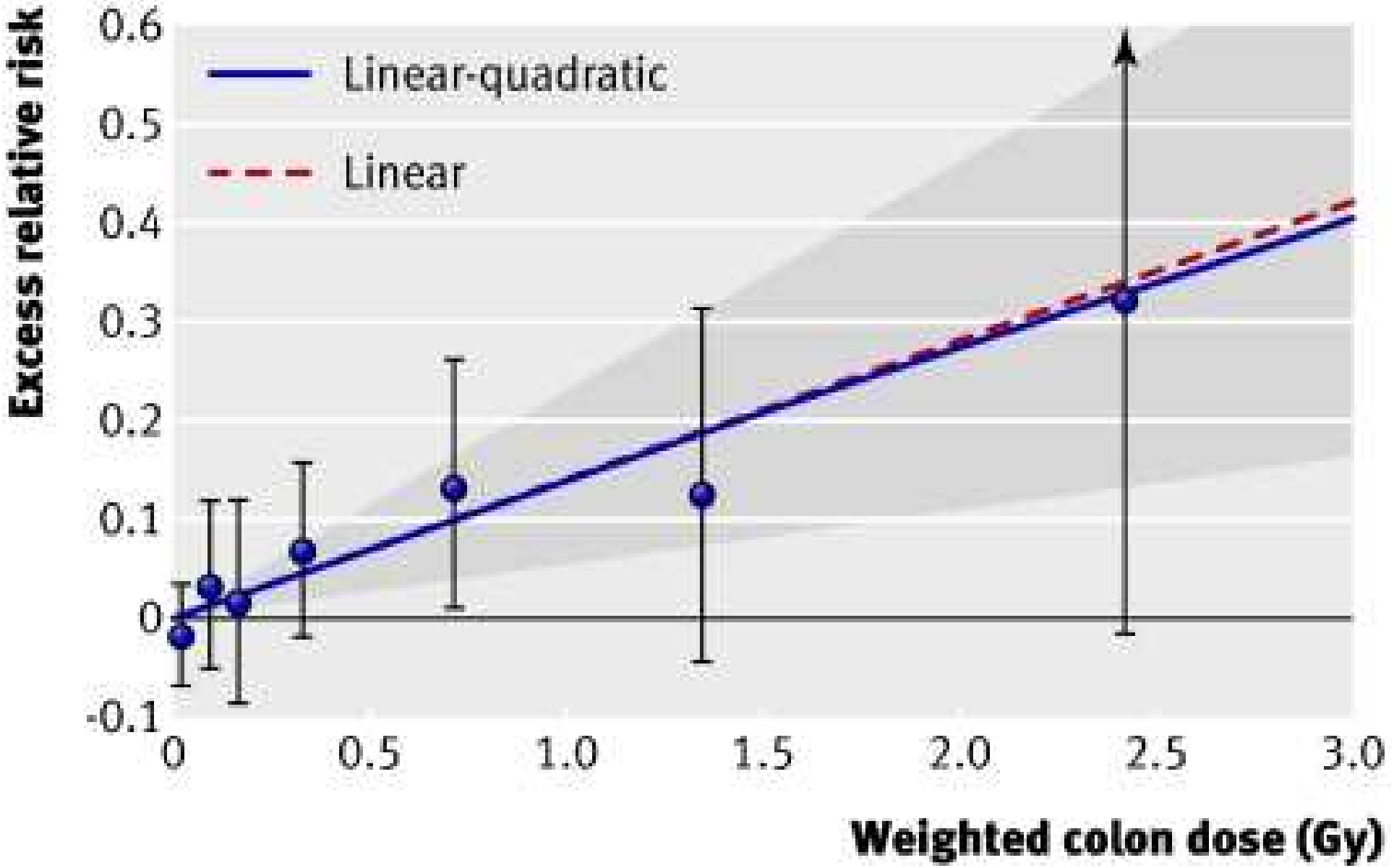
Cancer	Incidence in controls	Incidence in liquidators	increase
All sites	373.3	464.6	23%
Bladder	11.4	18.7	65%
Colon	16.7	22.2	33%
Lung	52.6	66.3	26%
Kidney	15.4	19.1	24%
Stomach	40.8	46.9	15%

source: Okeanov *et al* (2014)

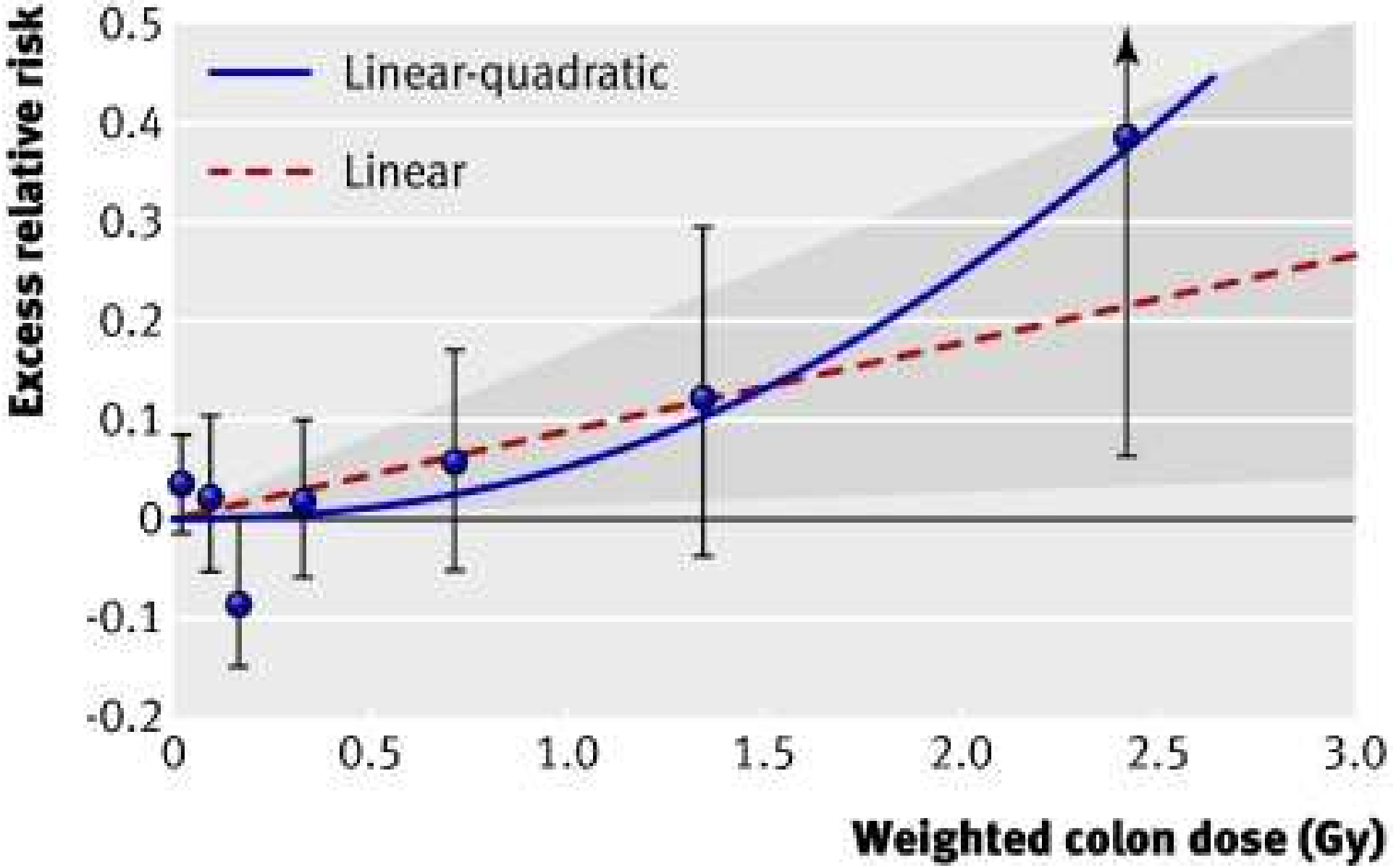
Radiogenic Cardiovascular Disease

- aetiology? inflammatory response?
- non-targeted effect of radiation?
- a stochastic effect? - long latency period, no threshold, progressive
- stroke+heart disease caused 1/3 of radiogenic deaths in atomic bomb cohort
- all cancer also caused 1/3 of radiogenic deaths in atomic bomb cohort

Cardiovascular Disease (LSS)



Stroke (LSS)


Excess relative risk
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
Linear-quadratic
Linear
0
0.5
1.0
1.5
2.0
2.5
3.0
Weighted colon dose (Gy)

Radiogenic Cardiovascular Disease - Risks

- Ivanov *et al*, 2000 (clean-up workers)
  ERR/Sv = 0.54 (95% CI 0.18 - 0.91)
- Shimizu *et al*, 2012 (LSS)
  ERR/Sv = 0.14 (95% CI 0.06 - 0.23)
- Buzunov *et al*, 2013
  observed risks down to 6-20 mSv!

Birth Defects

Major study on birth defects

150,000 births, 10 years, (Timchenko et al, 2014)

Frequency per 1000 live births	polluted areas	clean areas	% increase
all birth defects	26.10 ± 0.80	24.23 ± 0.47	7.7%
nervous system birth defects	1.09 ± 0.17	0.75 ± 0.08	45%

Down Syndrome

- Scotland (Ramsay *et al*, 1991)
- Southern Germany (Sperling *et al*, 1991)
- Finland (Harjulehto-Mervaala *et al*, 1992)*
- Hungary (Czeizel *et al*, 1993)*
- Sweden (Ericson and Kallen, 1994)
- Berlin (Sperling *et al*, 1994, 1994b)
- England (Bound *et al*, 1995)
- Belarus (Zatsepin *et al*, 2007) (26 obs: 9.84 exp; O/E ratio=2.64; CI=1.72-3.76)

Persistent ill health in children

Persistent ill health in children

- impaired lung function, increased breathing difficulties Svendsen *et al* (2010, 2015)
- decreased blood count Stepanova *et al* (2008) Lindgren *et al* (2015)
- increased immunoglobulin factors Titov *et al* (1995), McMahon *et al* (2014)
- increased anaemias and colds McMahon *et al* (2015)
- improvement with clean food McMahon *et al* (2015)

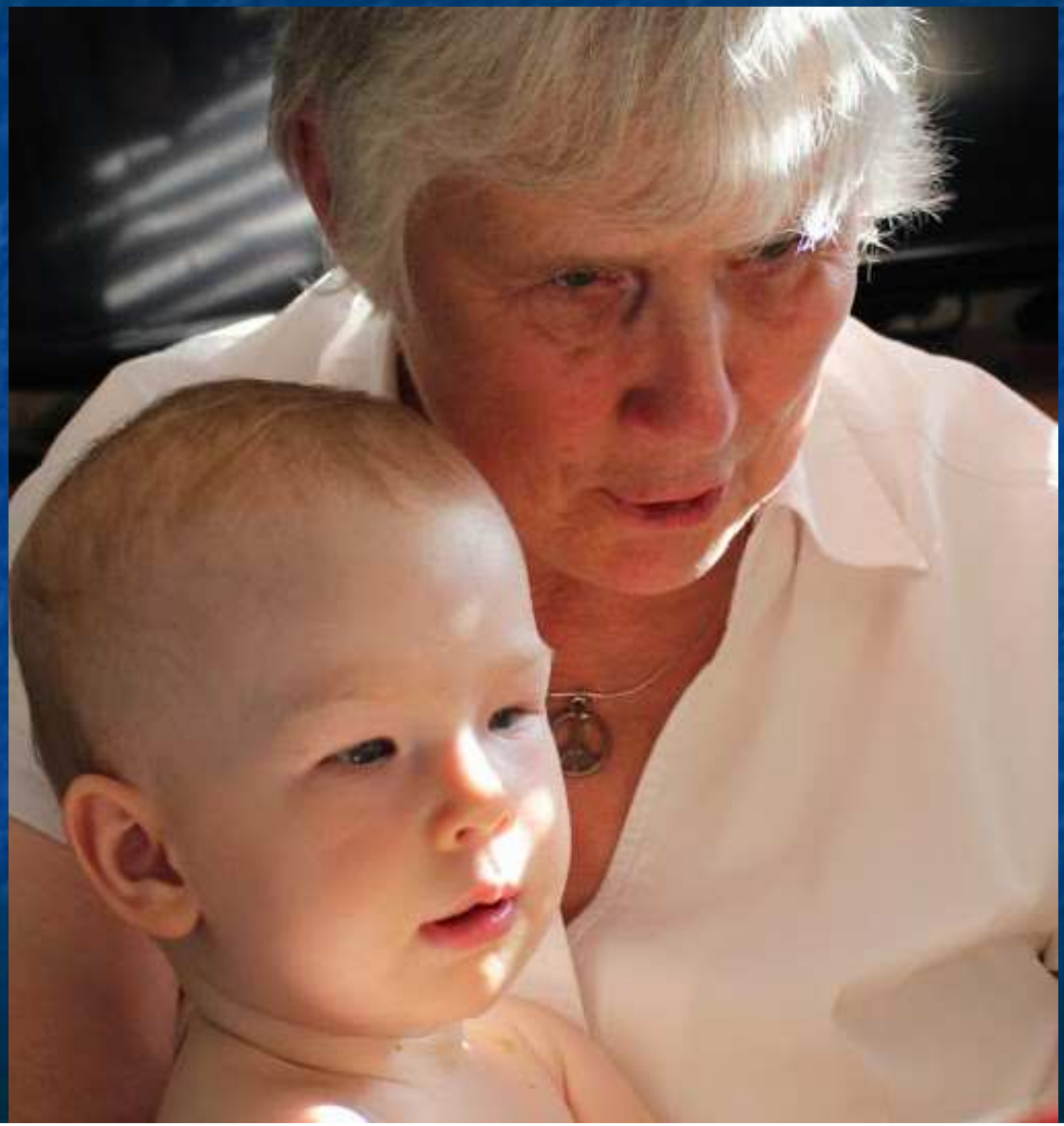
Chernobyl in a nutshell

- 5 million people in still live in highly contaminated areas
- 400 million people in less contaminated areas
- 42% of western Europe also seriously contaminated
- half of Chernobyl's fallout deposited on W Europe
- 40,000 fatal cancers of all types predicted
- 6,000 thyroid cancer cases, thousands more expected
- increased thyroid cancers in Austria and other western European countries
- increased radiogenic leukemia, cardio-vascular disease, breast cancers confirmed
- radiogenic birth defects, mental health effects
- children in contaminated areas suffer radiogenic illnesses

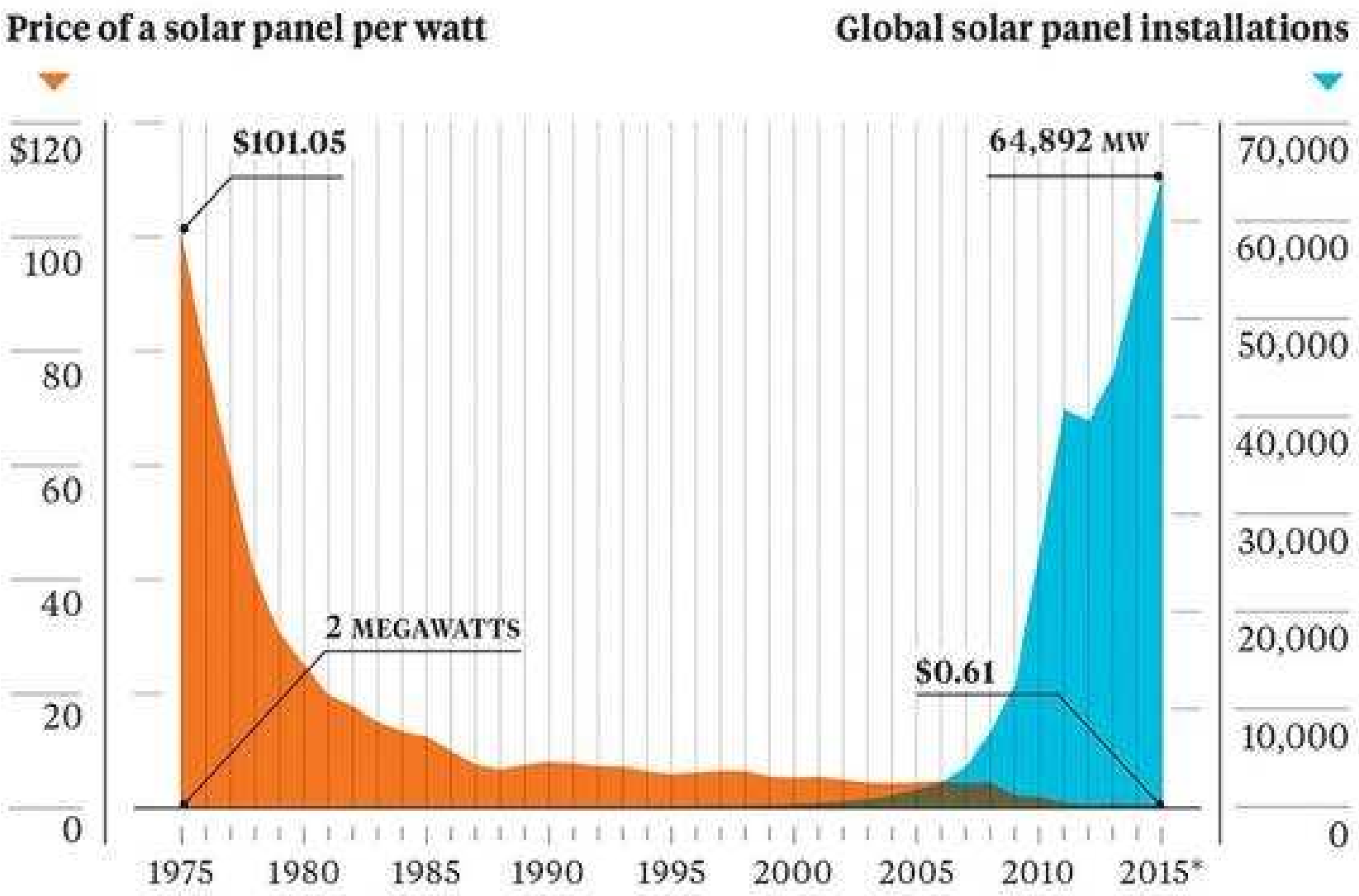
Chernobyl: conclusions

- nuclear power is a supremely unforgiving technology
- terrible consequences
- millions still in contaminated areas
- health effects still occurring
- need for more research in Europe
- need for more humanity towards affected peoples

Chernobyl Children Projects ✓



the future....


Price of a solar panel per watt
Global solar panel installations
$120
100
80
60
40
20
0
$101.05
2 MEGAWATTS
$0.61
64,892 MW
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1975
1980
1985
1990
1995
2000
2005
2010
2015*

Good References

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