



16th International Conference on Chemistry and the Environment

Informal recycling of electronic wastes in developing countries: challenges and solutions

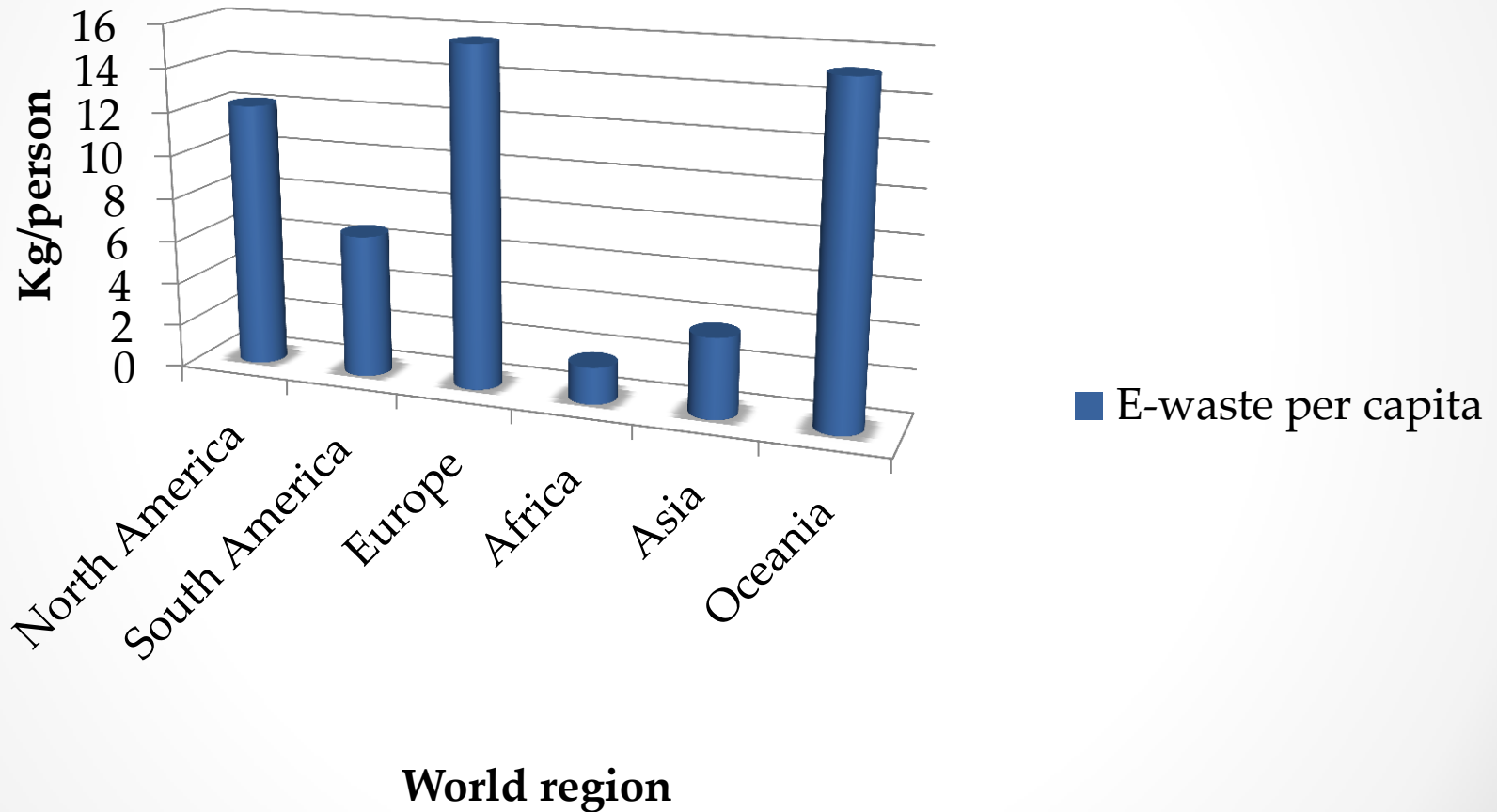
Diane Purchase



Out with the old ...



E-waste generated per capita in 2014



Global challenges of E-waste

- Chemical nature and global distribution?
- Environmental and health impact?
- Governance?
- Management strategy?

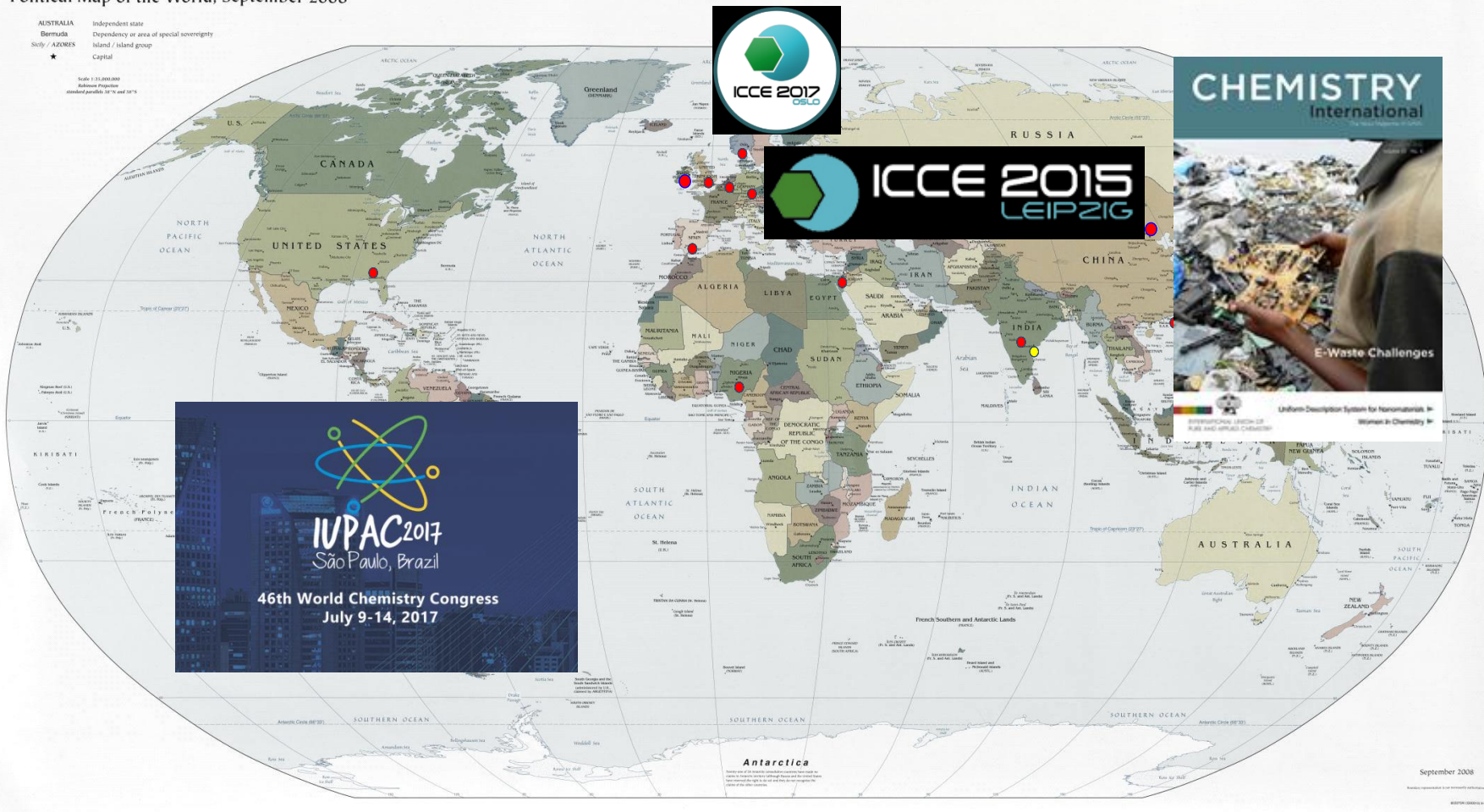


**Recommendations for
management approach**



The International Union of Pure & Applied Chemistry E-waste Project

Political Map of the World, September 2008



Chemical Nature and Global Distribution

...

Example - Elements typically found in a mobile phone

1

IA

11A

2

IIA

2A

3

IIIB

3B

4

IVB

4B

5

VB

5B

6

VIB

6B

7

VII B

7B

8

VIII

8

9

VIII

9

10

VIII

10

11

IB

1B

12

IIB

2B

13

IIIA

3A

14

IVA

4A

15

VA

5A

16

VIA

6A

17

VIIA

7A

18

VIIIA

8A

1

H

Hydrogen

1.008

2

He

Helium

4.003

3

Li

Lithium

6.941

4

Be

Beryllium

9.012

5

B

Boron

10.81

6

C

Carbon

12.011

7

N

Nitrogen

14.007

8

O

Oxygen

15.999

9

F

Fluorine

18.998

10

Ne

Neon

20.180

11

Na

Sodium

22.990

12

Mg

Magnesium

24.305

13

Al

Aluminum

26.982

14

Si

Silicon

28.086

15

P

Phosphorus

30.974

16

S

Sulfur

32.065

17

Cl

Chlorine

35.453

18

Ar

Argon

39.948

19

K

Potassium

39.098

20

Ca

Calcium

40.078

21

Sc

Scandium

44.956

22

Ti

Titanium

47.88

23

V

Vanadium

50.942

24

Cr

Chromium

51.996

25

Mn

Manganese

54.938

26

Fe

Iron

55.933

27

Co

Cobalt

58.933

28

Ni

Nickel

58.693

29

Cu

Copper

63.546

30

Zn

Zinc

65.39

31

Ga

Gallium

69.732

32

Ge

Germanium

72.61

33

As

Arsenic

74.922

34

Se

Selenium

78.09

35

Br

Bromine

79.904

36

Kr

Krypton

84.80

37

Rb

Rubidium

84.468

38

Sr

Strontium

87.62

39

Y

Yttrium

88.906

40

Zr

Zirconium

91.224

41

Nb

Niobium

92.906

42

Mo

Molybdenum

95.94

43

Tc

Technetium

98.907

44

Ru

Ruthenium

101.07

45

Rh

Rhodium

102.91

46

Pd

Palladium

106.36

47

Ag

Silver

107.868

48

Cd

Cadmium

112.411

49

In

Indium

114.818

50

Sn

Tin

118.710

51

Sb

Antimony

121.757

52

Te

Tellurium

127.6

53

I

Iodine

126.905

54

Xe

Xenon

131.29

55

Cs

Cesium

132.905

56

Ba

Barium

137.327

57-71

Lanthanide Series

72

Hf

Hafnium

178.49

73

Ta

Tantalum

180.948

74

W

Tungsten

183.84

75

Re

Rhenium

186.207

76

Os

Osmium

190.23

77

Ir

Iridium

192.22

78

Pt

Platinum

195.084

79

Au

Gold

196.967

80

Hg

Mercury

200.59

81

Tl

Thallium

204.383

82

Pb

Lead

207.2

83

Bi

Bismuth

208.980

84

Po

Polonium

[209]

85

At

Astatine

209

86

Rn

Radon

222

87

Fr

Francium

223

88

Ra

Radium

226

89-103

Actinide Series

104

Rf

Rutherfordium

[261]

105

Db

Dubnium

[262]

106

Sg

Seaborgium

[266]

107

Bh

Bohrium

[264]

108

Hs

Hassium

[269]

109

Mt

Meitnerium

[268]

110

Ds

Darmstadtium

[269]

111

Rg

Roentgenium

[272]

112

Cn

Copernicium

[277]

113

Uut

Ununtrium

unknown

114

Fl

Flerovium

[289]

115

Uup

Ununpentium

unknown

116

Lv

Livermorium

[293]

117

Uus

Ununseptium

unknown

118

Uuo

Ununoctium

unknown

57

La

Lanthanum

138.905

58

Ce

Cerium

140.12

59

Pr

Praseodymium

140.908

60

Nd

Neodymium

144.24

61

Pm

Promethium

144.913

62

Sm

Samarium

150.36

63

Eu

Europium

151.964

64

Gd

Gadolinium

157.25

65

Tb

Terbium

158.925

66

Dy

Dysprosium

162.50

67

Ho

Holmium

164.930

68

Er

Erbium

167.26

69

Tm

Thulium

168.934

70

Yb

Ytterbium

173.04

71

Lu

Lutetium

174.967

89

Ac

Actinium

227.028

90

Th

Thorium

232.038

91

Pa

Protactinium

231.036

92

U

Uranium

238.029

93

Np

Neptunium

237.048

94

Pu

Plutonium

244.064

95

Am

Americium

243.061

96

Cm

Curium

247.070

97

Bk

Berkelium

247.070

98

Cf

Californium

251.080

99

Es

Einsteinium

[254]

100

Fm

Fermium

257.095

101

Md

Mendelevium

258.1

102

No

Nobelium

259.101

103

Lr

Lawrencium

[262]

Alkali Metal

Alkaline Earth

Transition Metal

Semimetal

Nonmetal

Basic Metal

Halogen

Noble Gas

Lanthanide

Actinide

This periodic table does not take into account in what quantities and concentrations the elements have been used (only the smallest impurities are excluded). Neither does it take into account the form the element in question has been used in.

Source: Ormala E. 2015

Examples of hazardous chemicals in E-waste

Heavy metals and metalloids

- e.g. barium, mercury, aluminium, cadmium, copper
- e.g. arsenic

Brominated flame retardants

- e.g. hexabromocyclododecane (HBCDD), polybrominated diphenyl ethers (PBDE), polychlorinated biphenyl (PCB)

Plastics

- e.g. bisphenol-A, polychlorinated biphenyls (PVC)

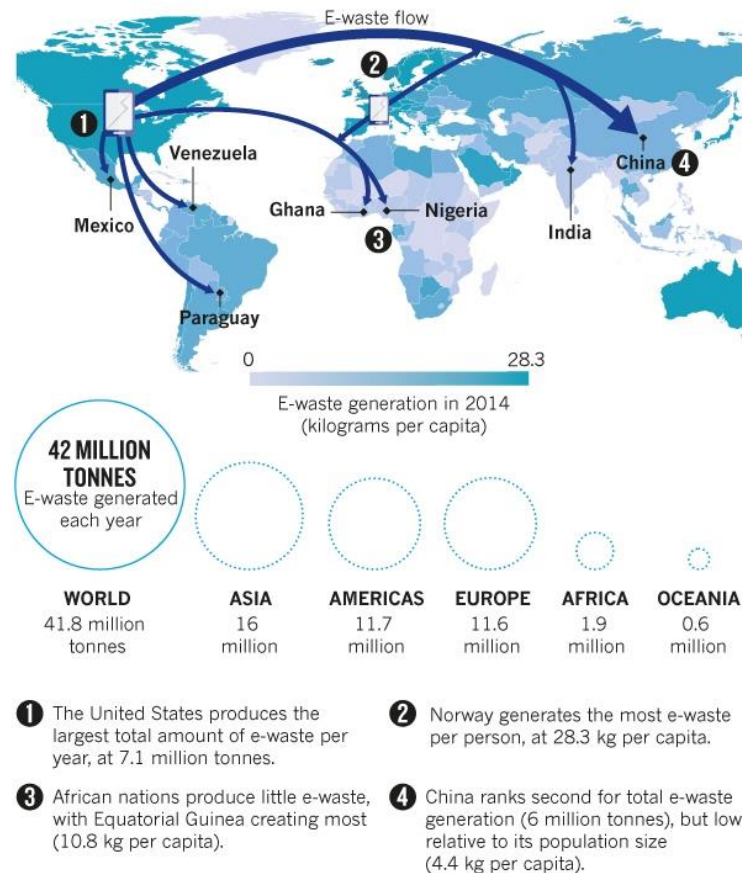
Lead Glass

- e.g. Lead

The known legal flow of E-waste

UNFAIR FLOW

Most electronic waste from developed countries ends up in poor nations that lack regulation. China processed around 70% of the world's e-waste in 2012; the rest goes to India and other countries in eastern Asia and Africa, including Nigeria.



... and the illegal dark trade



Source: <http://www.sustainelectronics.illinois.edu/policy/international.cfm> [accessed 7th September, 2016]

Health and Environmental Impacts ...

Treatment of E-waste

Dismantling and
pre-processing

Recycling of metal
contained E-waste

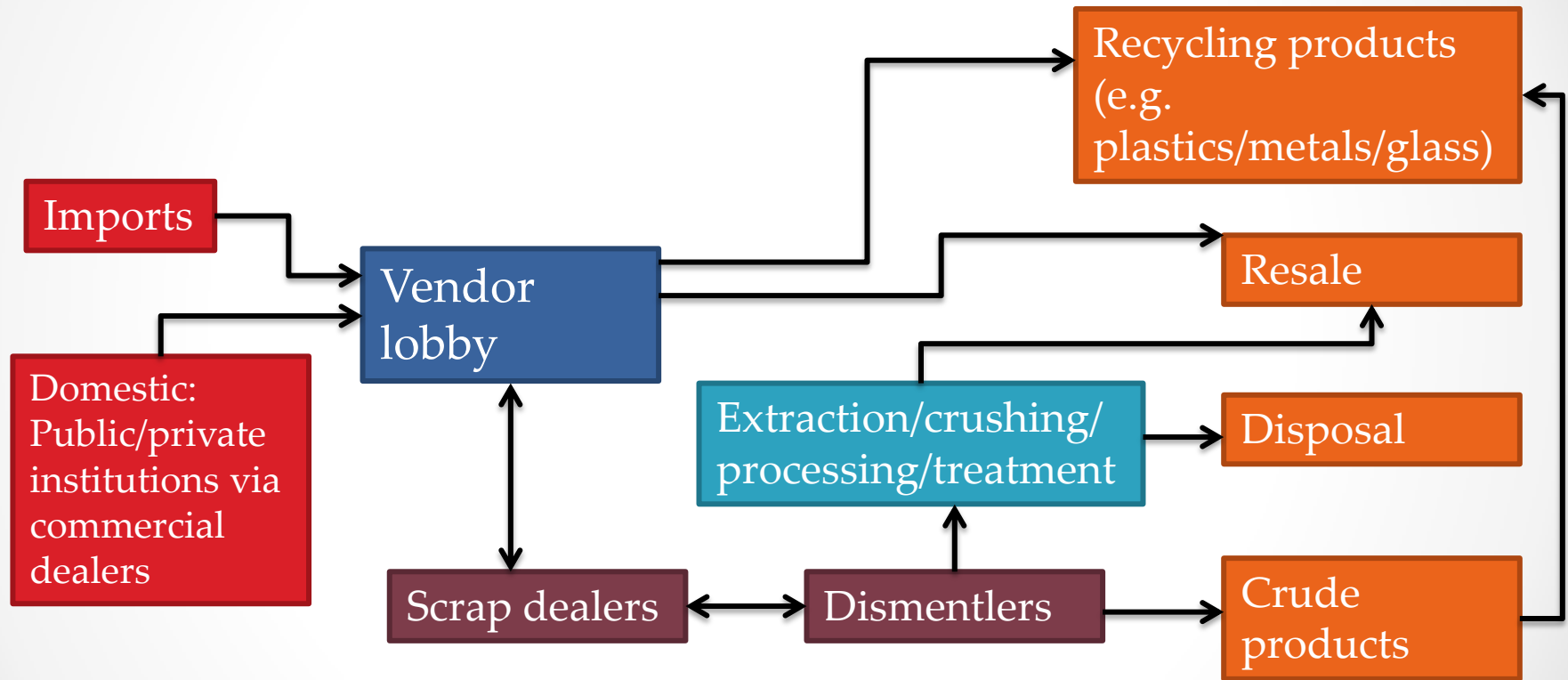
Recycling of E-
waste plastics



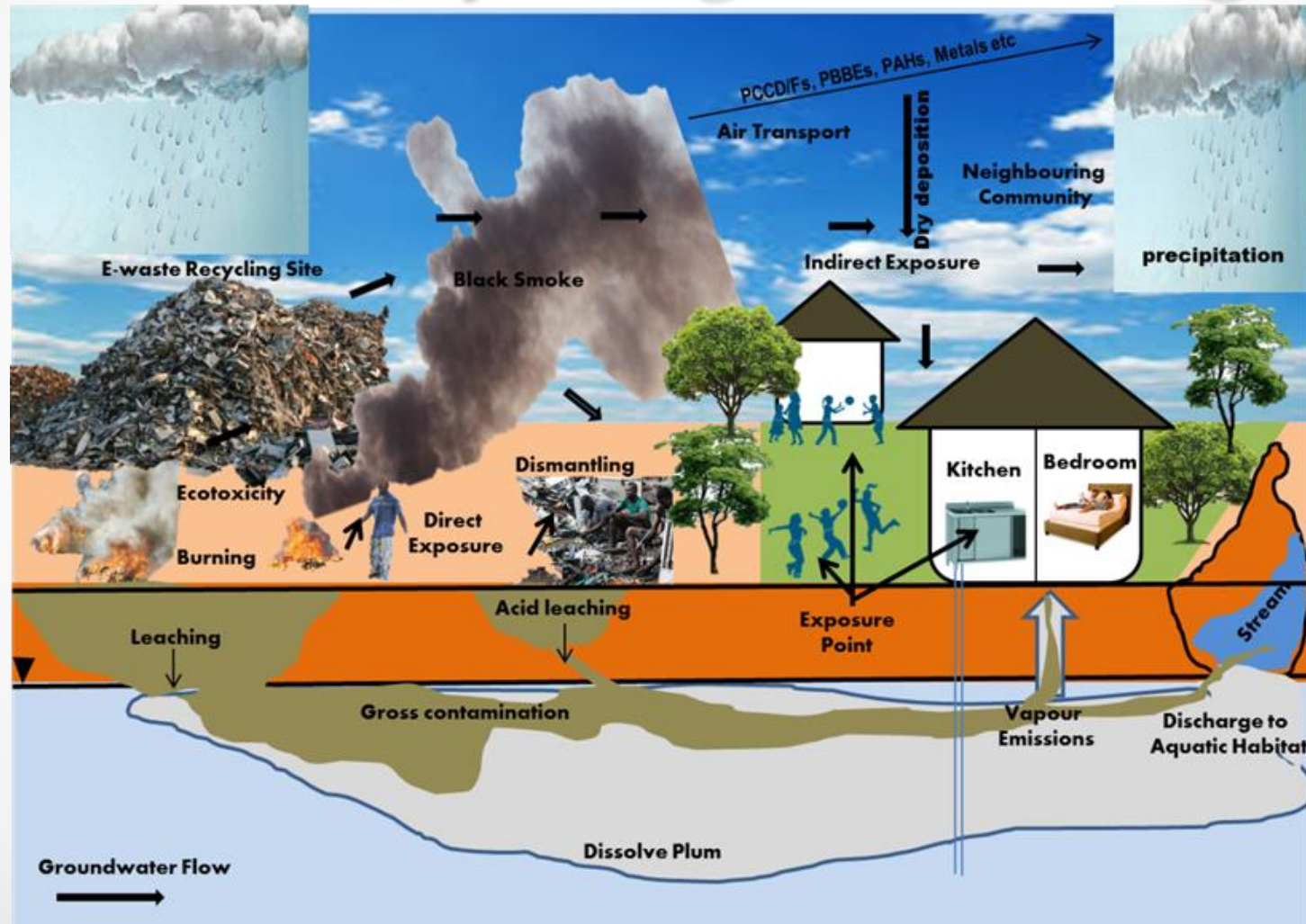
Waste Printed Circuit Board Recycling

Source: <https://www.linkedin.com/pulse/what-e-waste-pcb-recycling-process-plant-julia-ge>

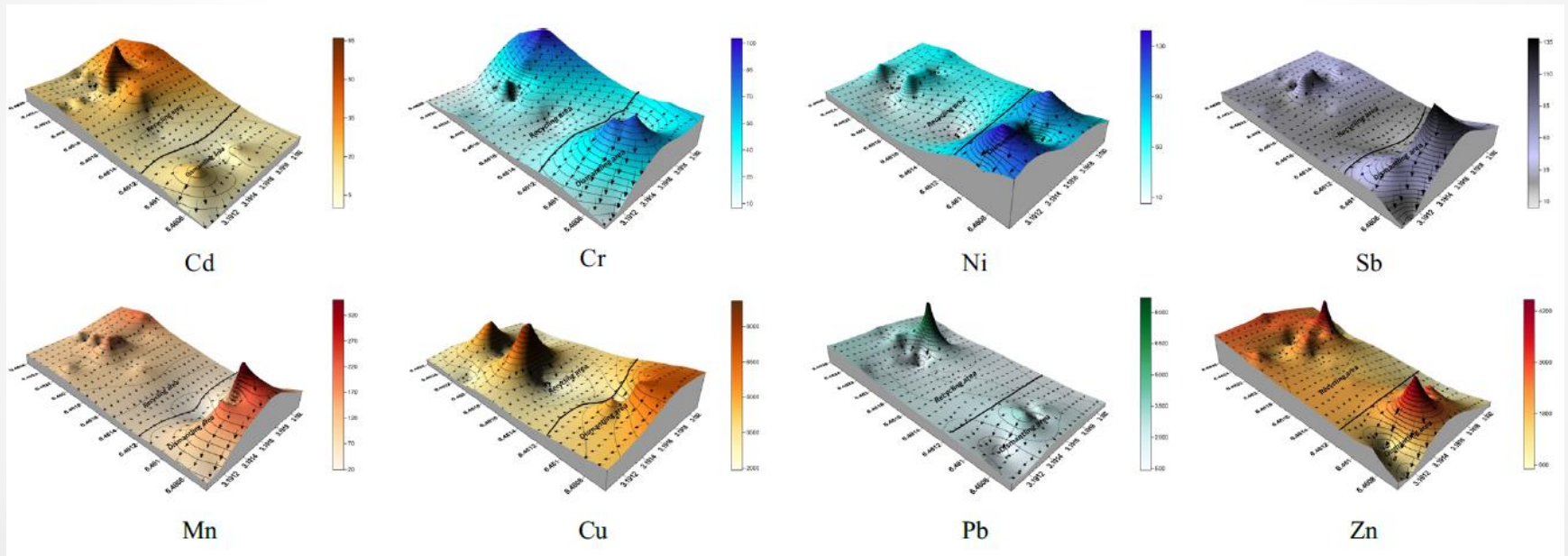
Example - Trade chain practice in India



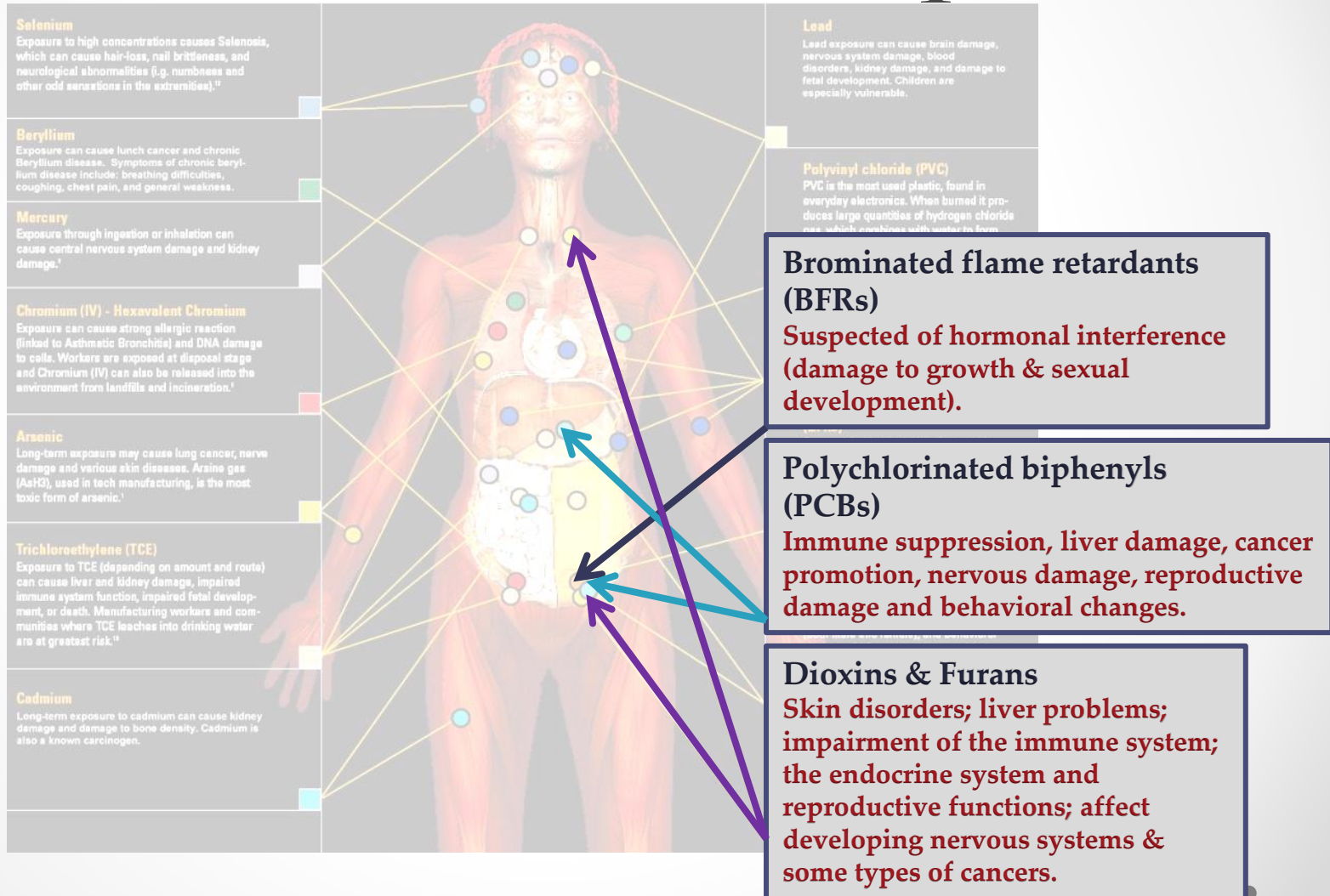
Conceptual model of a typical E-waste recycling site in Nigeria



Environmental Impact - spatial distribution of heavy metals in the study site



Potential health impacts



Adapted from: <http://ewise.co.nz/the-impact-of-ewaste/>

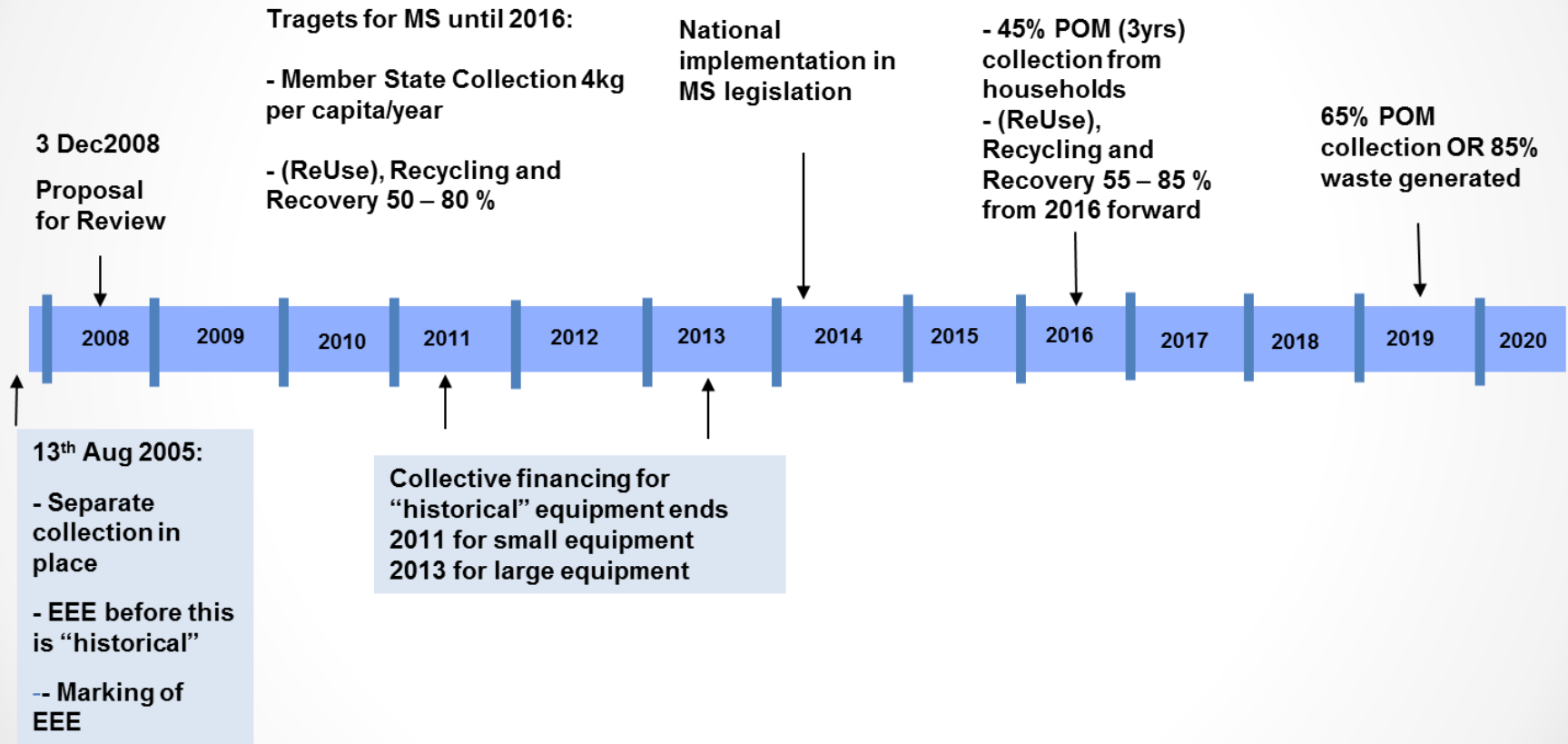
Governance

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Key legal framework

- Basel Convention
- Waste Shipment Regulation (WSR)
- Restriction of Hazardous Substances Directive (RoHS)
- Extended Producer Responsibility (EPR)
- Directive on Waste Electrical/Electronic Equipment (WEEE)

WEEE directive in EU "take-back" regulation



POM (3yrs) = put on market during previous 3 years

Challenges in the implementation of regulations and policy

- Different implementation
 - harmonized policy ≠ harmonized implementation
 - temporal & cultural dimension about waste
 - political unwillingness to regulate corporations too strictly
 - Difficult implementation
 - Finding illegal trade = needle in haystack (risk assessment)
 - Requires expertise (not present with all agencies)
 - Limited resources
 - Information with different agencies
 - Different agencies with different goals
 - Prosecution & Sentencing:
 - demanding investigative work
 - slow prosecution
 - low fines
 - Transnational trade: different jurisdictions, awareness, economics
-
-

E-waste as a criminogenic market?

■ Case of Ghana:

- Different priorities/concerns (no legislation on e-waste)
- Massive informal collection & recycling
- Local consumption of new/second hand products

'You can make money by "recycling" e-waste in poorer environmental and social conditions, since this provides you the precious metals with lower labour costs' (Corporate respondent 13).

Bisschop, L. (2015). Governance of the illegal trade in e-waste and tropical timber: case studies on transnational environmental crime. Green Criminology Series, Ashgate Publishing. (ISBN 978-1-4724-1540-0)

There's more to governance than government

- Understanding the big picture
- Harmonized rules are needed to facilitate economically sustainable solutions
- A formal global protocol on E-waste trading
- Strengthen domestic regulations
- Encourage transfer of knowledge e.g. monitoring, processing and recycling
- Stakeholders' responsibilities

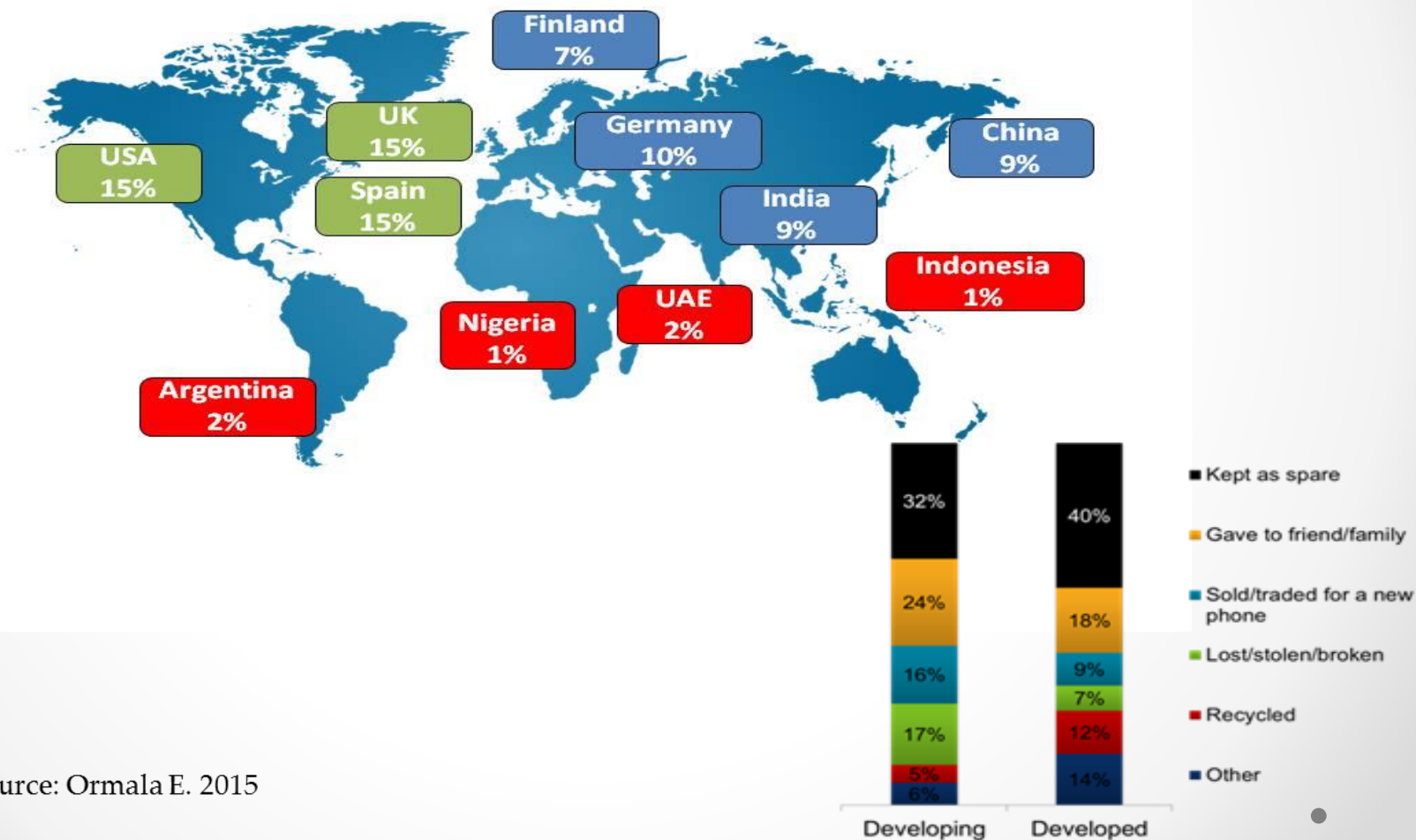
E waste Management

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Making E-waste management sustainable

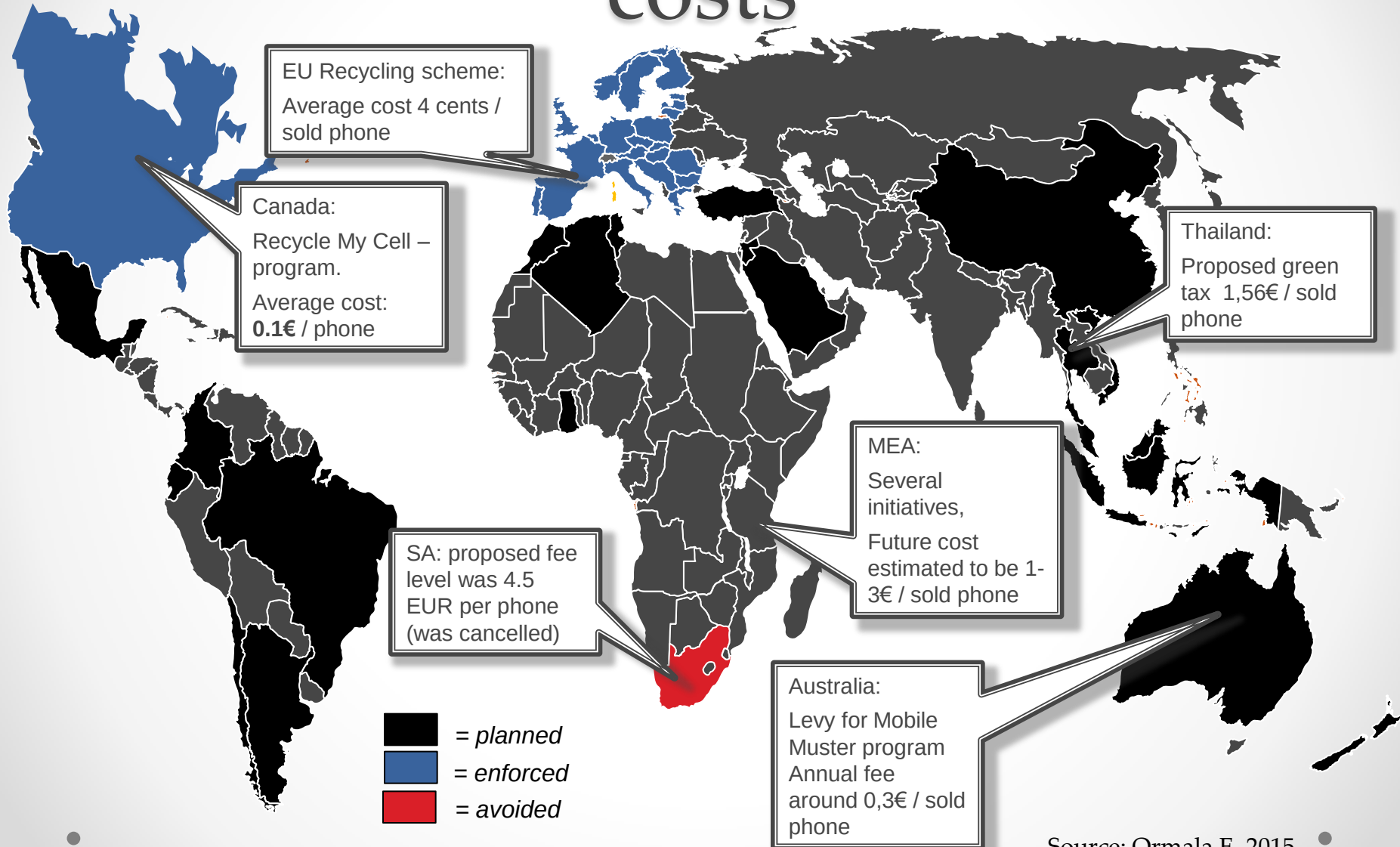
- Less wasteful consumption
- Circular economy
- Cleaner production & smaller material footprint
- Reverse logistics credits
- Life cycle analysis to identify environmentally sound end-of-life option
- Better treatment and disposals
- e-waste valorization

Example: Improve recycling behaviour-mobile phones



Source: Ormala E. 2015

Examples of E-waste recycling costs



Examples - Advances in material science for cleaner production

- Synthesis of heteroarchitectures formed by graphene oxide for low cost high performance supercapacitors
- High performance supercapacitors - polypyrrole nanotubes coated with Ni(OH)_2
- Hybrid materials for hybrid energy storage – supercapacitor and batteries in one
- Renewable polymeric materials for electronic applications

Examples - Advances in recycling technologies for metals recovery

Recycling technology	State of recovery metals	Species and effect of recovery metals	Advantages of environmental and technological aspect
Pyrometallurgy	pure solid metals	almost all metals; high recovery rate	totally-commercial; owing some dust chamber and exhaust gas treatment plant
Mild extraction	solution	almost all metals; recovery rate related to the reagents and reaction condition	low toxicity; simple and easy accessibility; relative low environment damage
Biometallurgy	Solution	only for a few specific metals; considerable recovery rate for Cu, Zn, Au etc	environment-friendly; low cost of investment
Electrochemical	pure solid metals	only for specific metals; high recovery rate	high recovery efficiency; low cost of investment; mature technology
Supercritical	solid mixture of metals	almost all metals; high recovery rate	high recovery efficiency; low cost of investment; low environment damage
Vacuum metallurgy	solid single metal	only for high vapor pressure metals; high recovery rate	environment-friendly; short technological process

‘There is no such thing as waste ...’

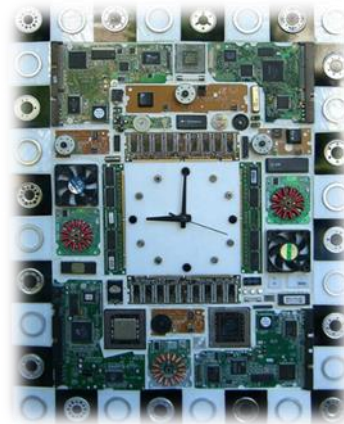
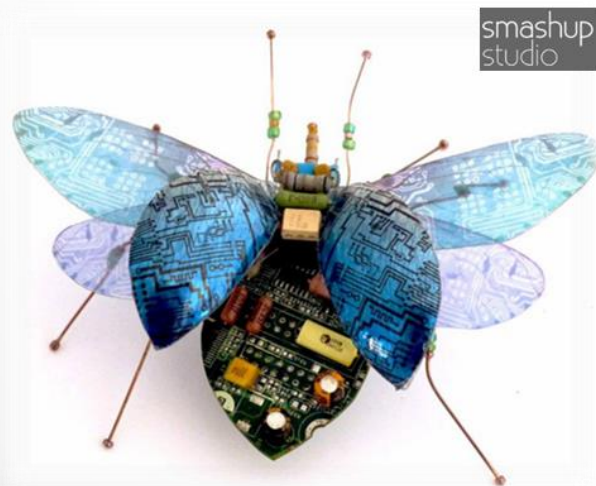


<http://www.electronicsspecifier.com/around-the-industry/do-you-have-a-goldmine-in-your-pocket>

- Also contains rare earth minerals
- From cathode-ray-tube funnel glass to zeolites
- Indium from LCD display
- From old printed circuit boards to Cu-Sn nanoparticles

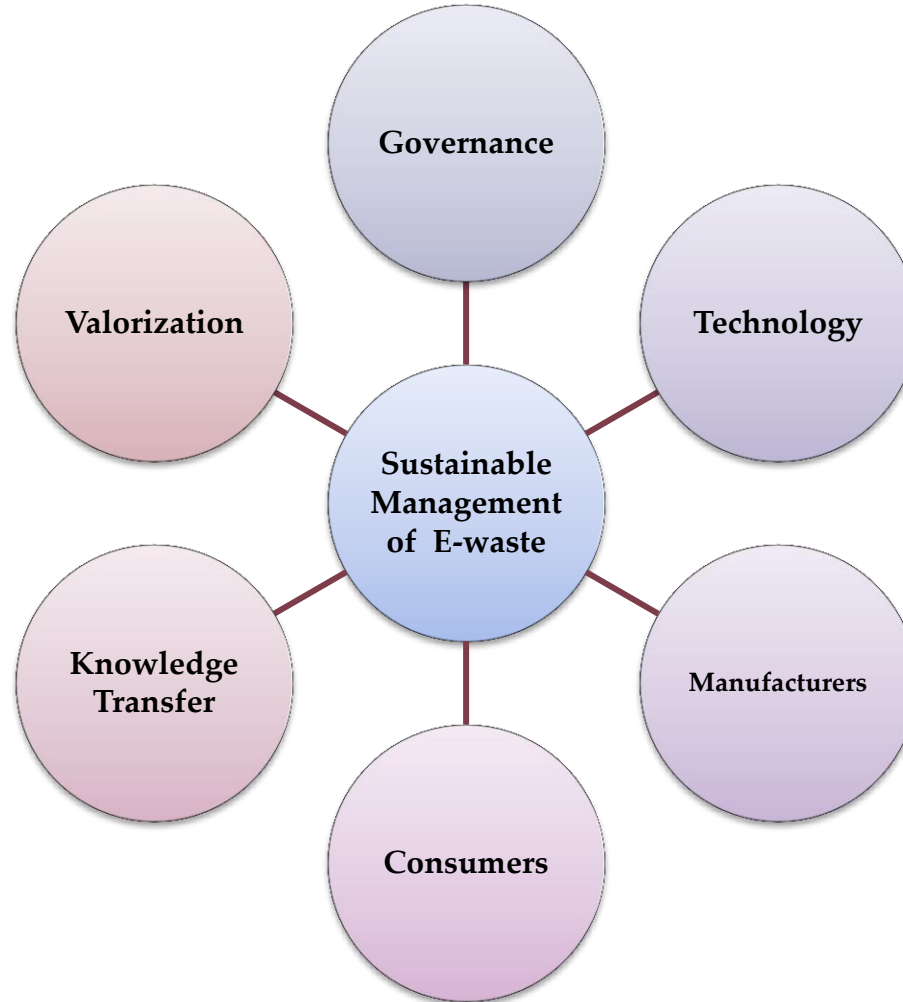
Second chances

- Electronic waste-derived aluminosilicate for wastewater treatment
- Recycle e waste -plastics and particleboard as wood-plastic composite
- Polymers from waste printed circuit boards reinforcing as fillers in polypropylene composites
- E-waste plastic powders as asphalt binder additives
- E-waste art



Computer parts clock by Wendy Birchmire

Conclusion



The IUPAC e-waste task group

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World by Susan Stockwell (2011)