Evaluation of the Ecological Costs and Benefits of Fire Safety

— A Case Study of Brominated Flame Retardants

（臭素系難燃剤）

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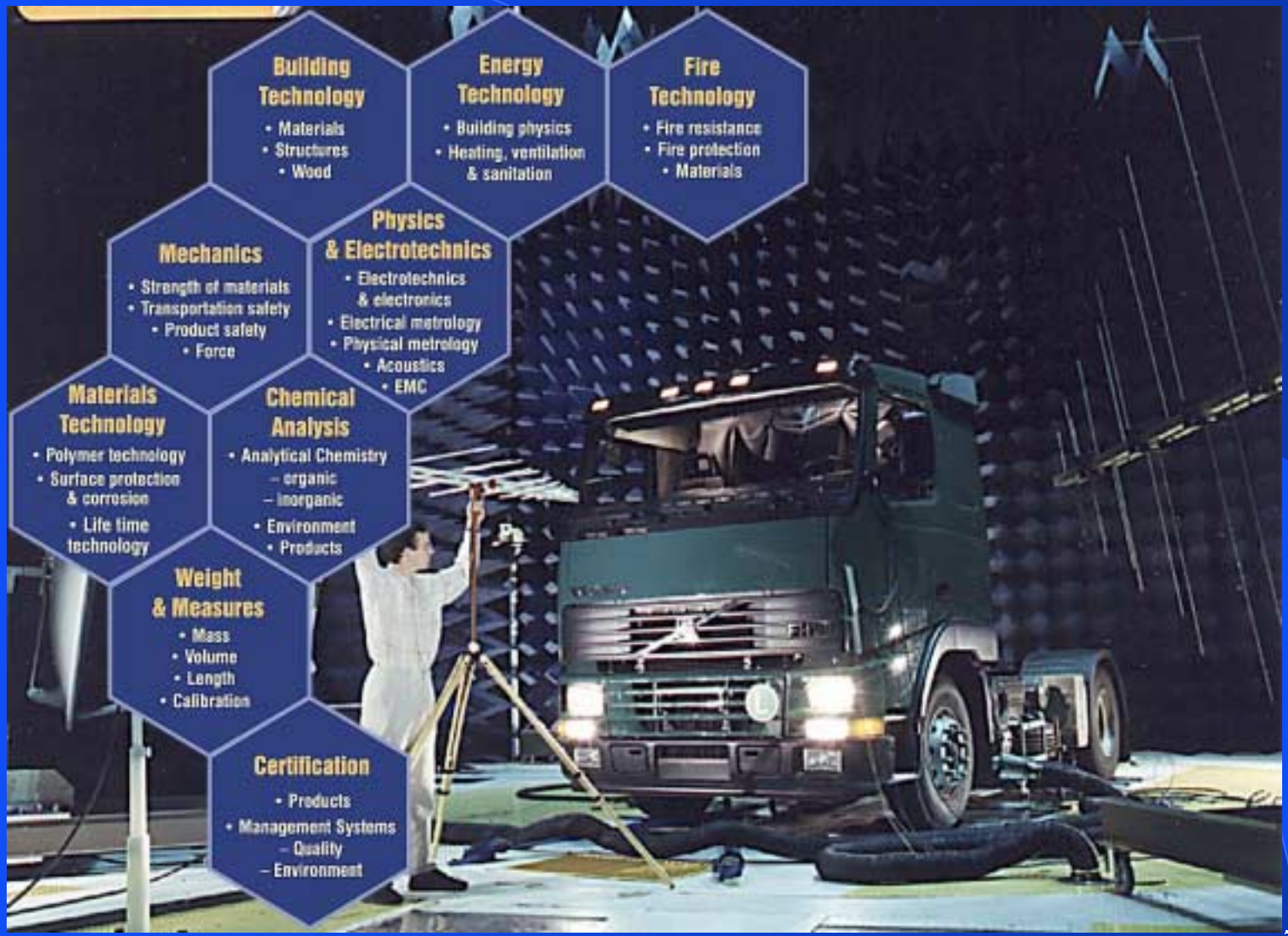
Building Technology
• Materials
• Structures
• Wood
Energy Technology
• Building physics
• Heating, ventilation & sanitation
Fire Technology
• Fire resistance
• Fire protection
• Materials
Mechanics
• Strength of materials
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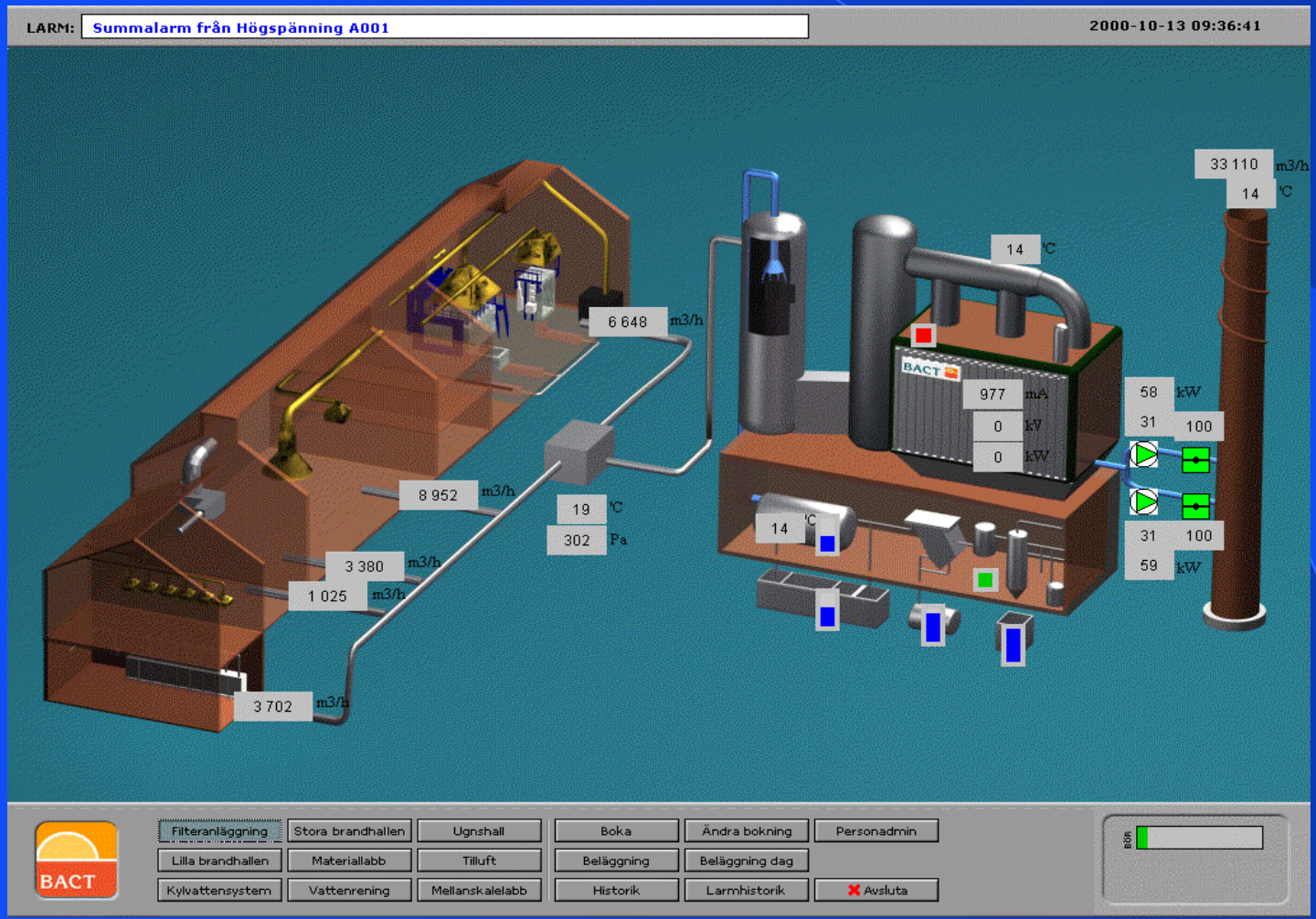
• Life time technology
Chemical Analysis
• Analytical Chemistry
– organic
– inorganic
• Environment
• Products
Weight & Measures
• Mass
• Volume
• Length
• Calibration
Certification
• Products
• Management Systems
– Quality
– Environment

SP Fire Technology

SP Fire Technology

- staff 50 at Fire Technology (50% R&D)
- staff 30 in the Chemical Analysis Lab.
- extensive chemical analysis laboratory
  - ✓ CG/MS, FTIR, Adsorbants, impinger sampling, TOF-SIMS, TOF-MALDI
- extensive fire testing facilities

Laboratory Resources



Fire-LCA

— A New LCA Model to Establish the Environmental Cost of Fire Safety

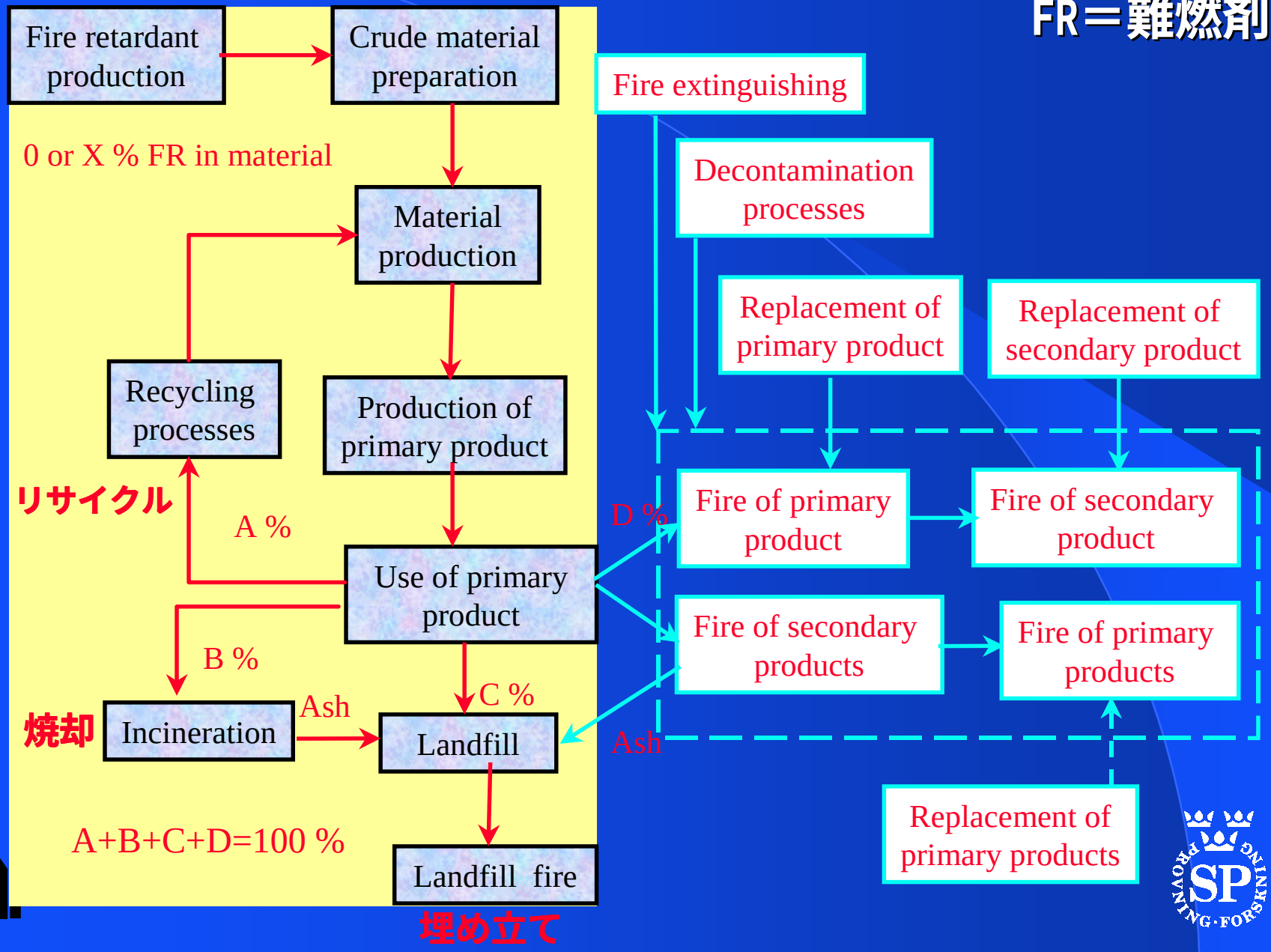
Aim

Evaluate degree to which environmental benefits of a flame retardant counterbalance environmental cost of production and use

Prime objectives of LCA

1. provide picture of the product's environmental impact
2. aid understanding of consequences of human activities
3. identify "HOT SPOTS"

FR＝難燃剤


Fire retardant production
Crude material preparation
0 or X % FR in material
Material production
Recycling processes
Production of primary product
リサイクル
A %
Use of primary product
B %
C %
焼却
Incineration
Ash
Landfill
A+B+C+D=100 %
Landfill fire
埋め立て
Fire extinguishing
Decontamination processes
Replacement of primary product
Replacement of secondary product
D %
Fire of primary product
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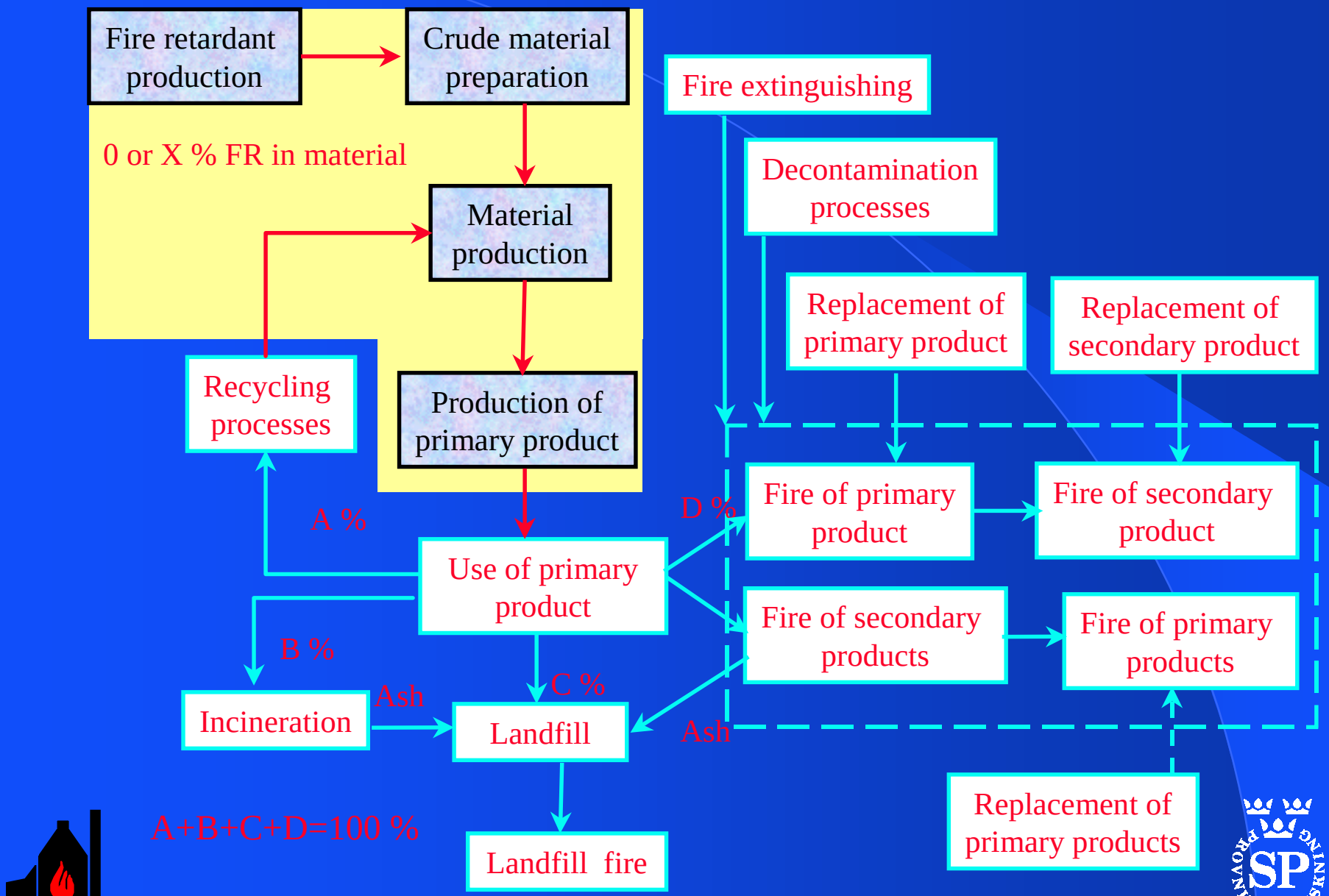
Fire of primary products
Ash
Replacement of primary products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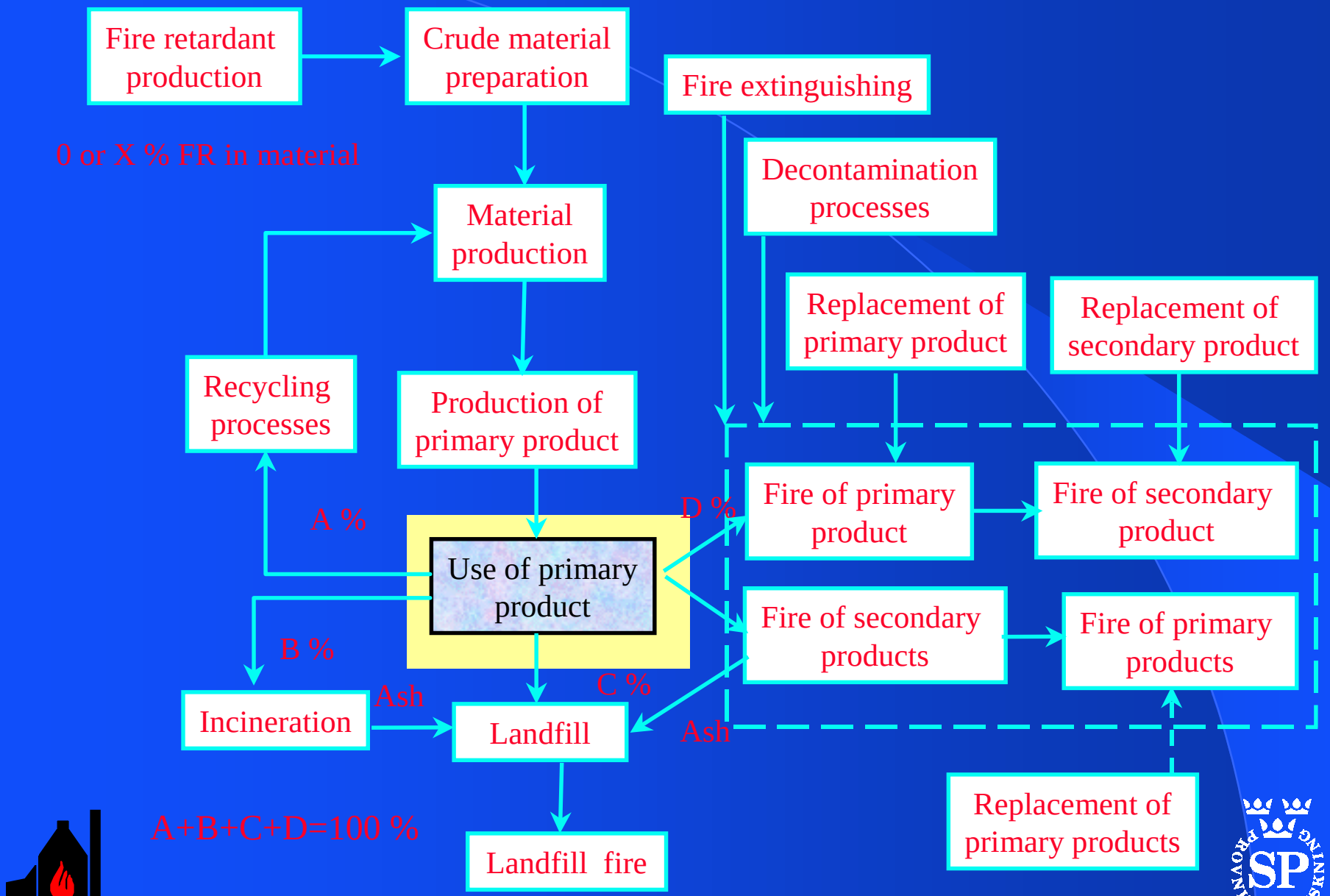
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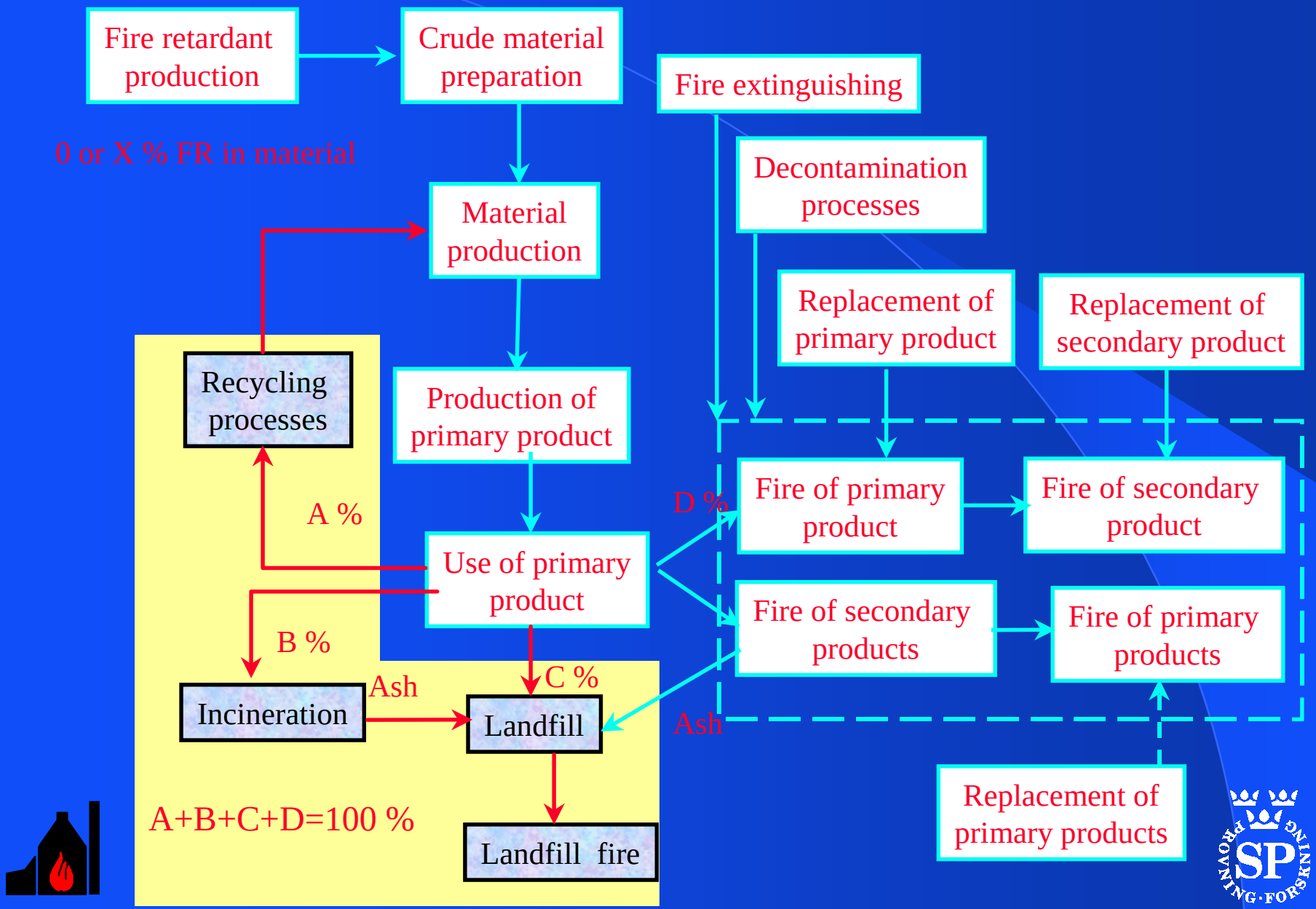
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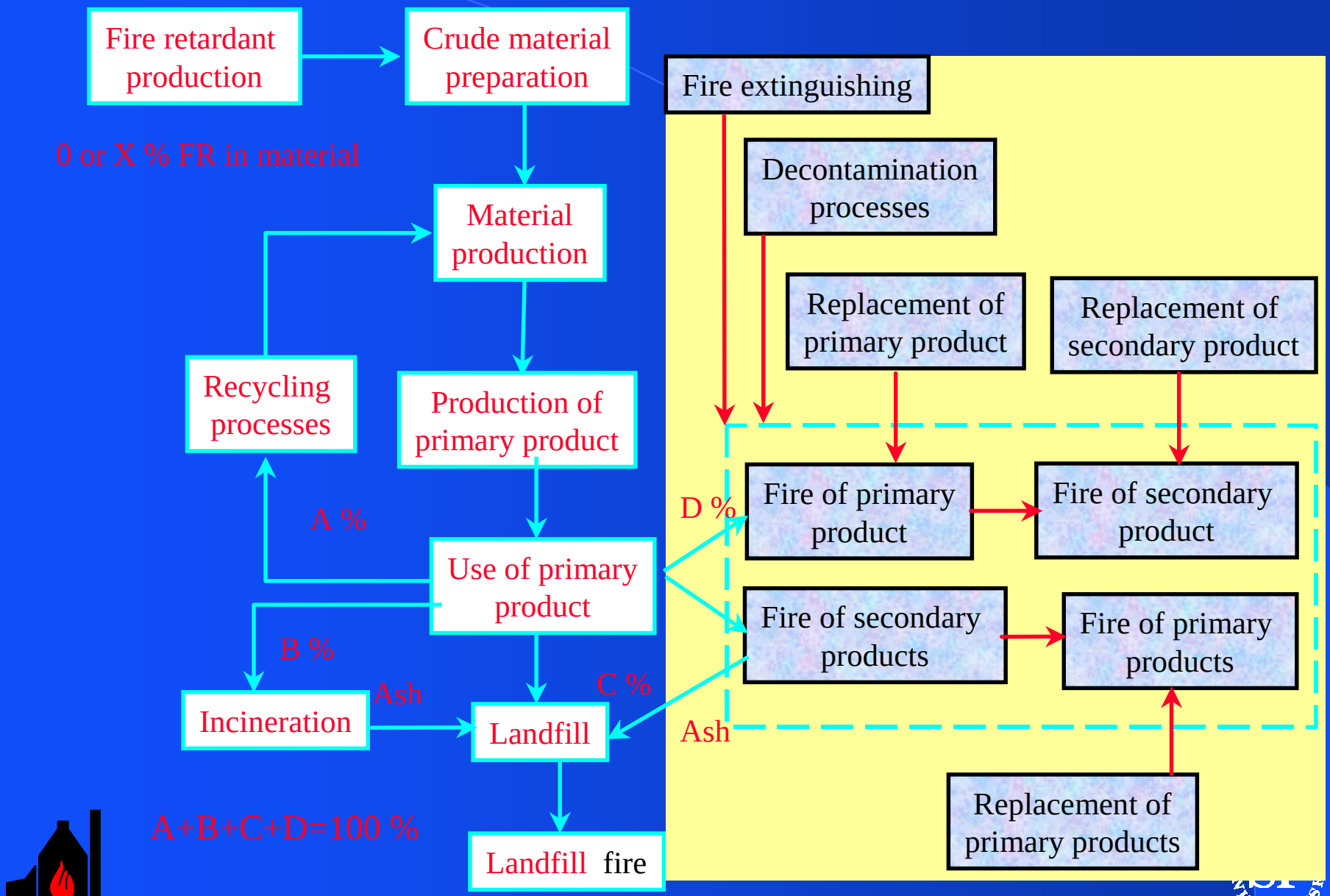
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Fire Statistics

- most countries keep detailed fire statistics
- variation between sources within a country and between different countries
  - Fire brigades → large fires
  - Insurance companies → both large and small
  - Europe vs. USA

TV Case Study — Aim

Investigate the environmental impact of a

TV with HB enclosure

（欧州仕様）

relative to that of a

TV with V0 enclosure

（米国仕様）

TV Fire statistics (1)

- **1996 study for DTI by Sambrook Research International**

  ”…first point of ignition is from within the structure of the TV…The resultant fire will have breached the envelope of the TV…”

- **Similar TV fire frequency throughout Europe**

TV Fire statistics (2)

- **statistics very different from different sources (eg Sweden, 1994):**
  - 2500 TV Fires (Insurance Federation)
  - 150-250 TV Fires (SEMKO)
- **Vällingby study resolved question**
  - 100 TV Fires/10^6 TVs/year, internal ignition
  - 65 TV Fires /10^6 TVs/year, external ignition
  - 160 TV Fires/ 10^6 TVs each year, enclosure NOT breached

SP PROVNING · FORSKNING

TV Fire statistics (3)

- US Statistics: 5 TV Fires /10^6 TVs/year, essentially minor

TV Fire Severity

Severity	Frequency %	LCA category	#TVs in model
Fire restricted to TV	35	58	minor
Fire spread beyond TV	53	88	full TV
Major damage to room	5	8	full room
Major damage to dwelling	5	8	full house
Building destroyed	2	3	full house

- ✓ additional 160 minor TV Fires/10^6 TVs each year (Insurance Federation)

10^6 TVs, 1 year

Swedish TV			**US TV**		
Primary	**F**	**R**		**F**	**R**
160 minor, 30% replace		×	160 minor, 30% replace		×
58 minor, 100% replace		×	5 minor, 100% replace		×
88 TV only	×	×			
8 full room	×	×			
11 full house	×	×			
Secondary					
4 full house (6 TV only)	×	×	4 full house (6 TV only)	×	×

FIRE EXPERIMENTS

Full-scale Experiments

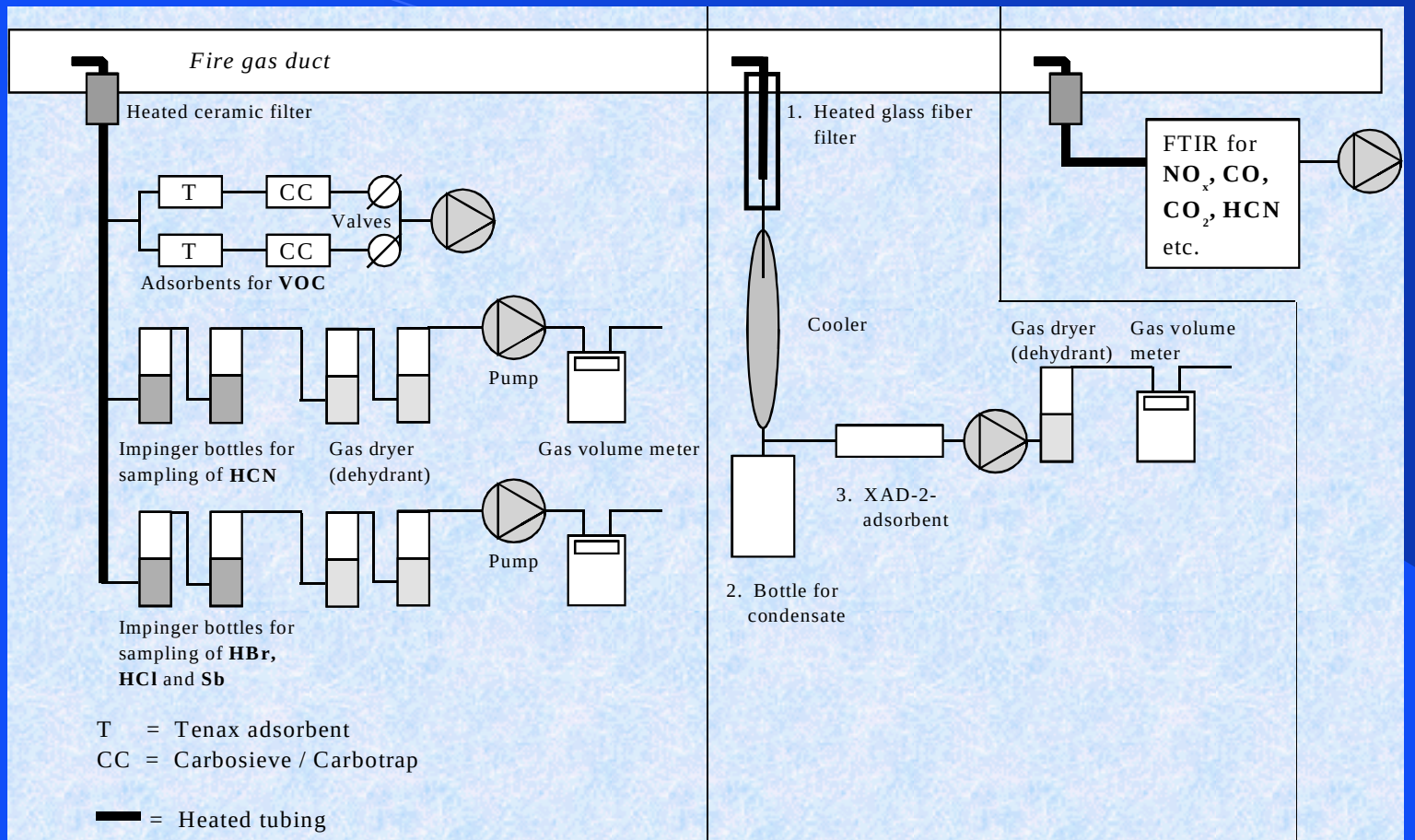
- TV - free burn
  - Swedish TV
  - US TV
- Lounge room
  - Swedish TV in furnished room (2 ×)
  - US TV in furnished room

Measurements

- HRR, t_{ig}, smoke obscuration etc
- CO, CO_2, HBr, HCl, HCN, NO_x
- Medium sized HCs, eg., phenol, styrene
- PAH （多環芳香族炭化水素）
- Cl/Br- dioxins and furans
- FR survival fraction （難燃剤残存物）

Chemical Analysis

Species	Mode of measurement
CO, CO_2	IR
O_2	paramagnetism
HBr, HCl, HCN, NO_x	FTIR
small/medium organics	adsorbents + GC-MS/FID
Sb	impinger bottles + ICP-MS
dibenzodioxins/furans	adsorbent + GC-MS
deca-BDE	
deca-BB	
PCB	
PAH	



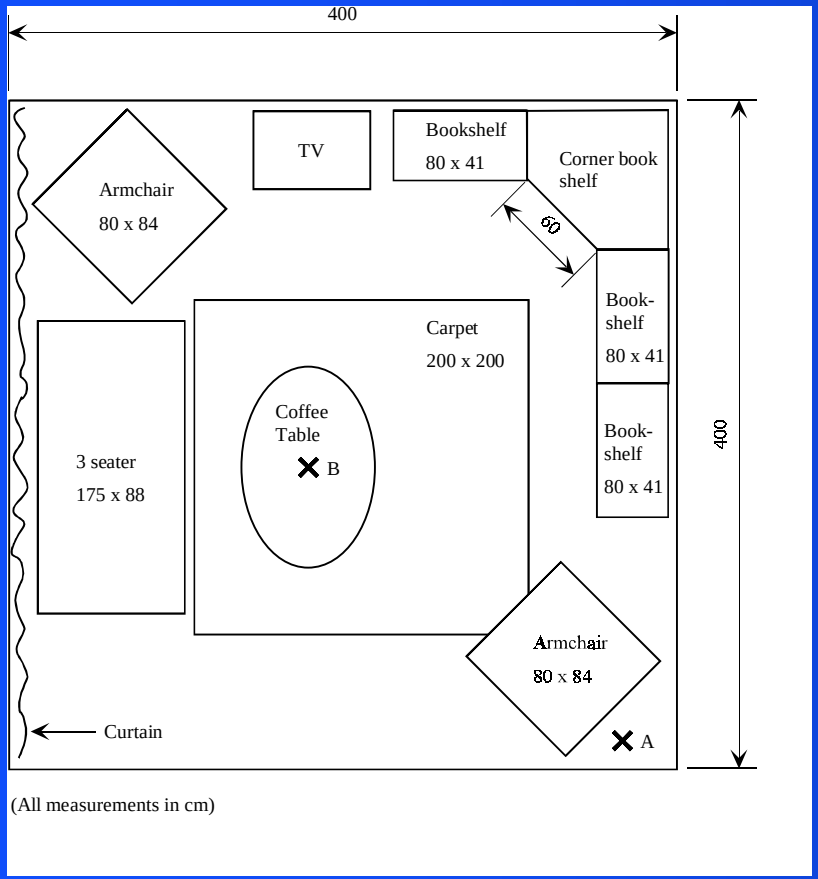
Sampling of VOCs, hydrogene bromide (HBr), hydrogene chloride (HCl), hydrogene cyanide (HCN) and Antimony (Sb)

Sampling of PAHs, PCBs, PBBs, TBBP A, PBDE, dioxins, furans etc.

US TV Test

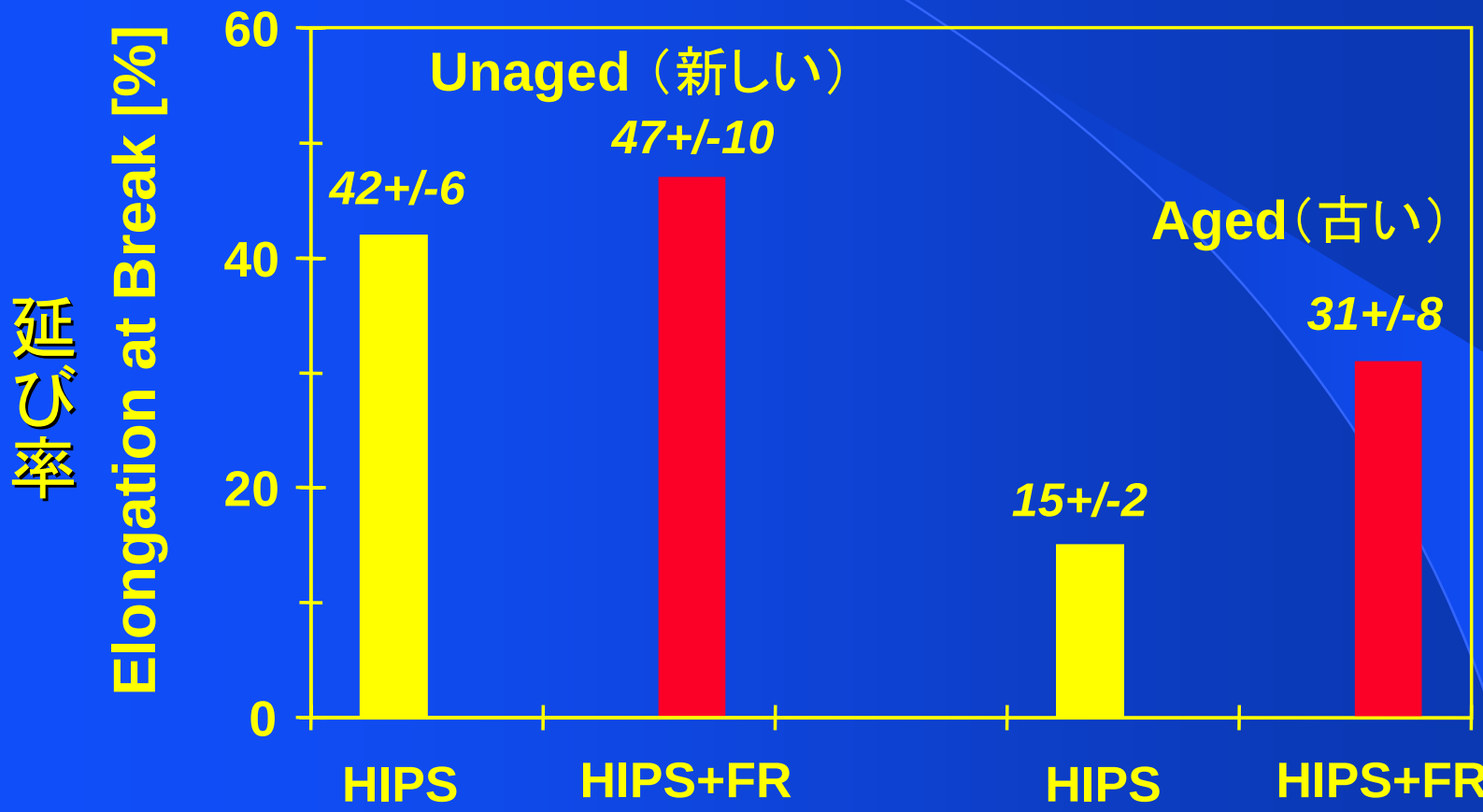
European TV Test

TV/Room Tests



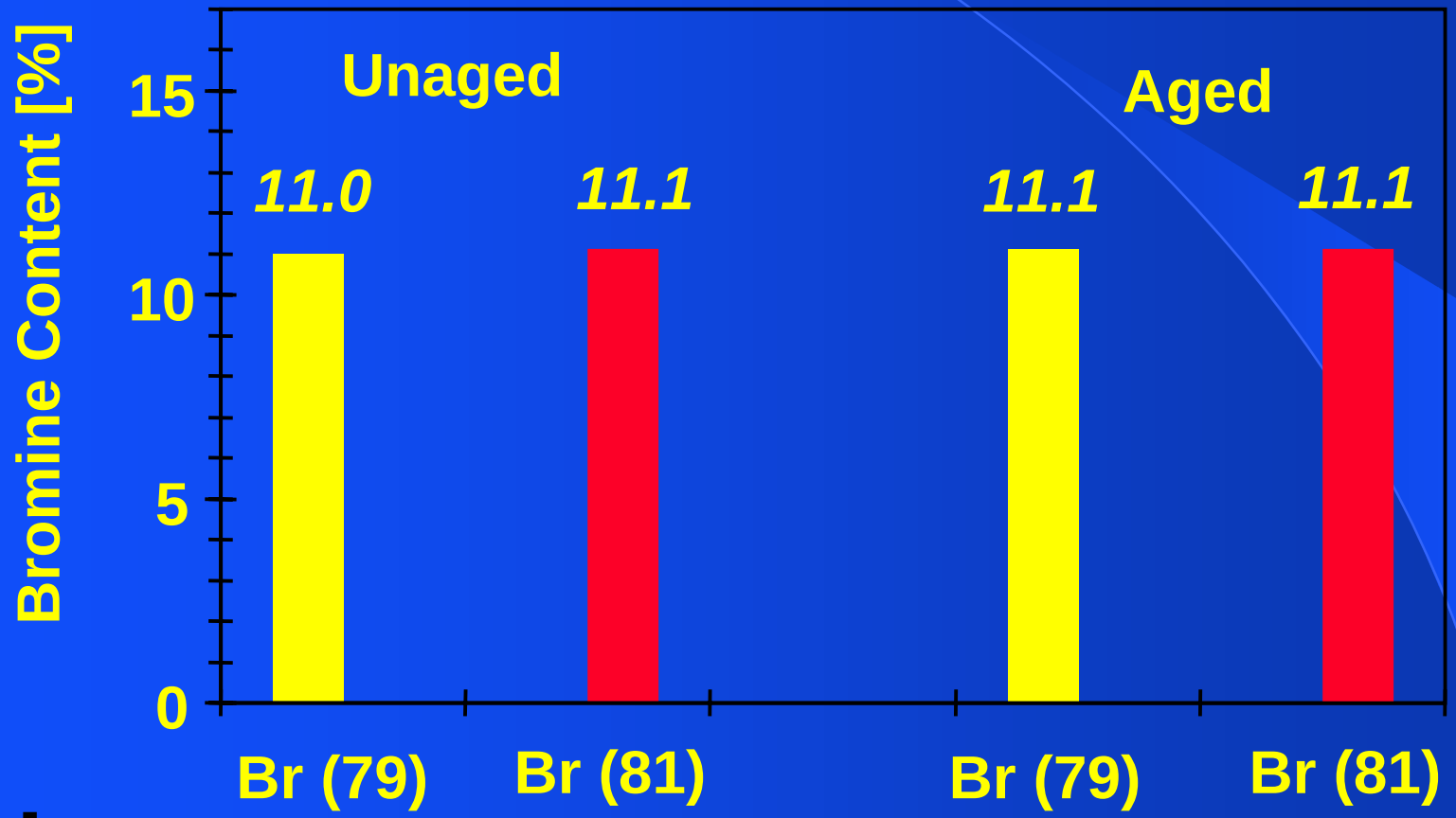
Material Recycling - extruded samples

Mechanical Testing （強度テスト）



(Impact strength – similar qualitative behaviour)

Bromine Content （臭素含量）



Ageing and Recycling

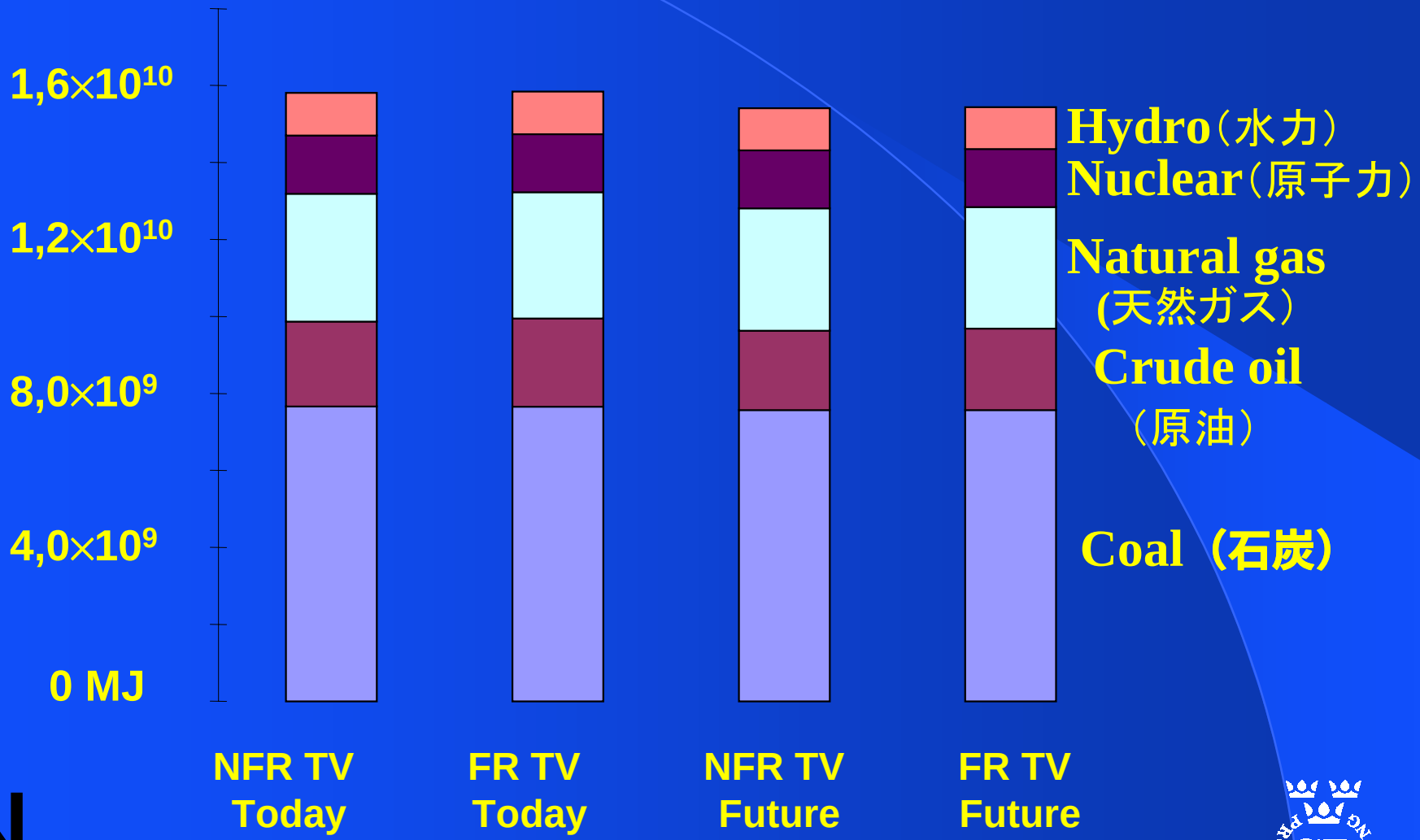
- same qualitative ageing and recycling behaviour for FR(**難燃剤**) and NFR(**難燃剤を含まない**) material
- no evidence of deca-BDE(**10臭素化物**) migration from sample
- no evidence of degredation of deca-BDE in sample
- retention of fire behaviour in FR-HIPS

LCA RESULTS

Scenarios

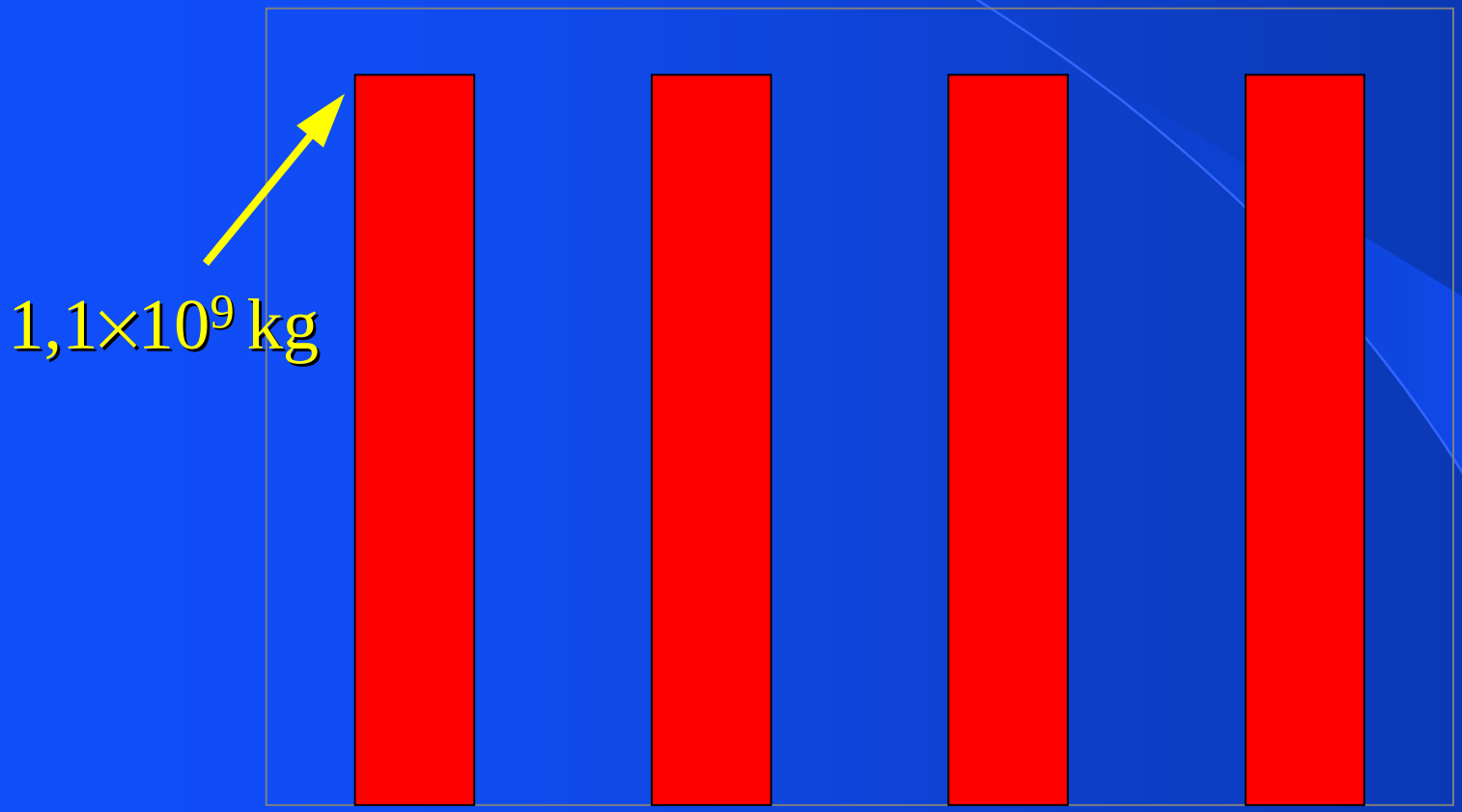
Present	Future
1 % Incineration	1 % Incineration
2 % Disassembly (リサイクル)	89 % Disassembly
~97 % Landfill	~10 % Landfill
(+ Fires)	(+ Fires)

Energy Use



(10^6 TV sets, 10 years)

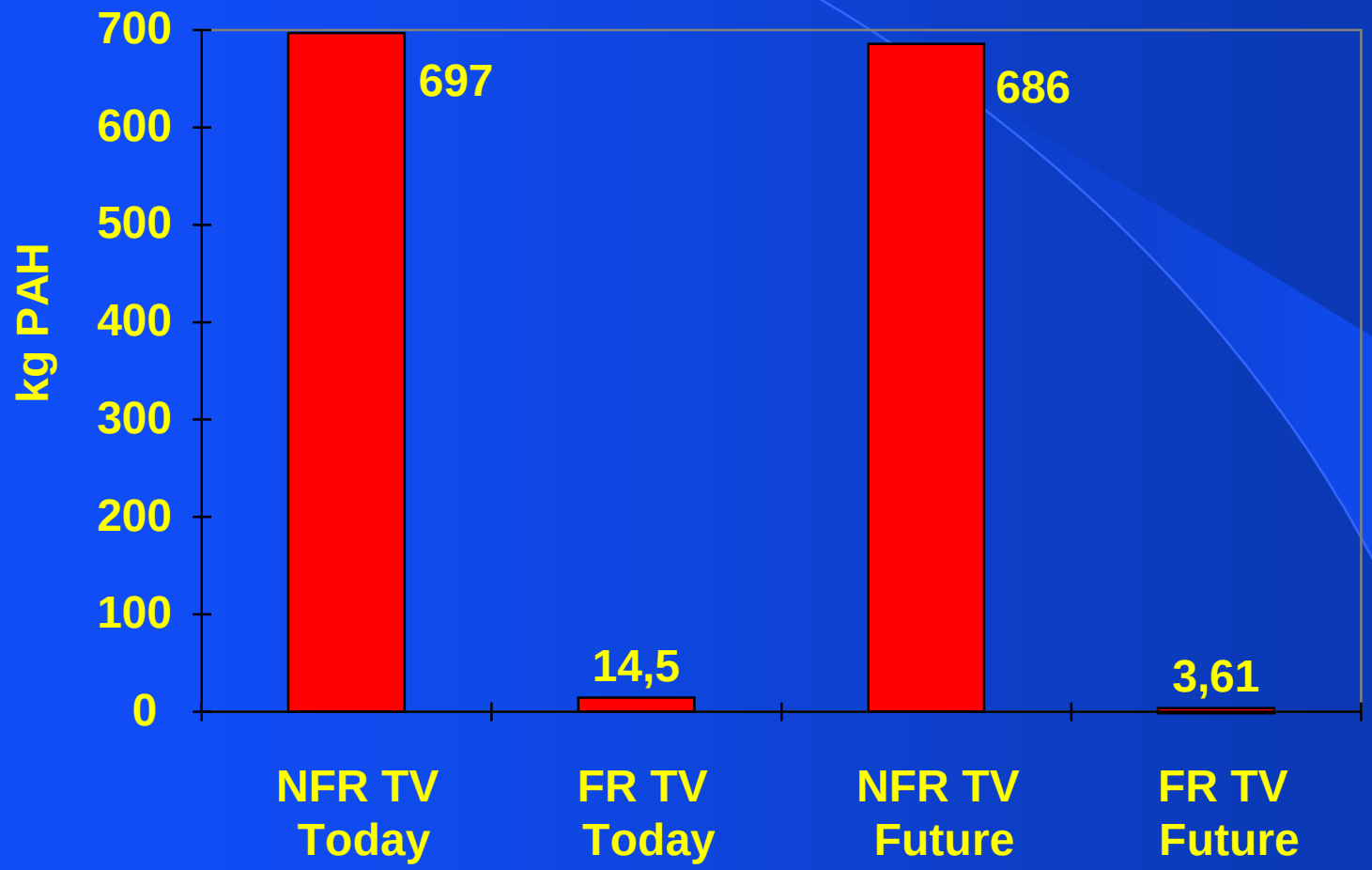
CO_2 emissions to air



(10^6 TV sets, 10 years)

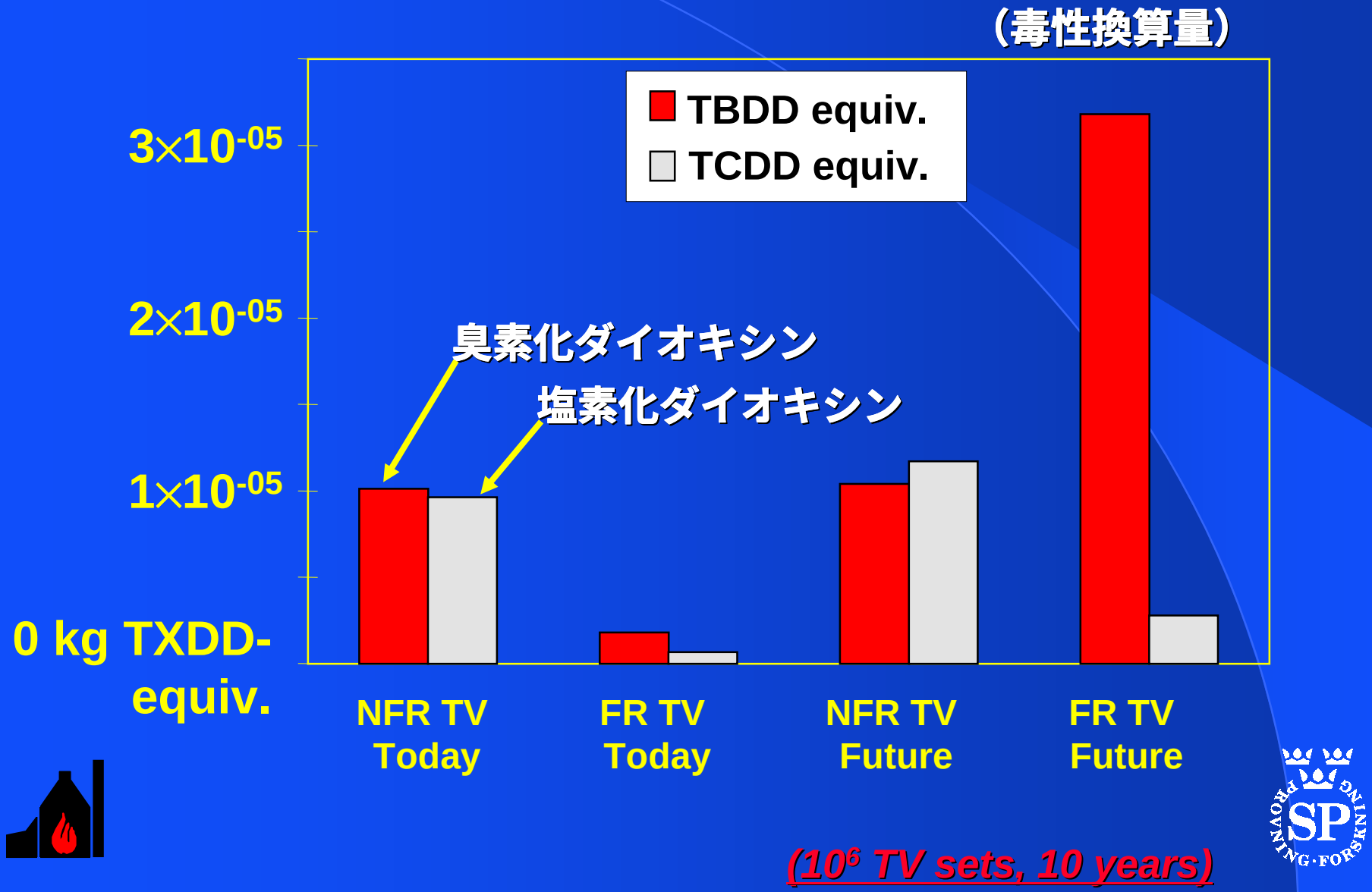
PAH emissions to air

（多環芳香族）



(10^6 TV sets, 10 years)

TXDD-Equiv. emissions to air



(10⁶ TV sets, 10 years)

Why PAH, dioxins and furans lower for FR TV ?

- These species are minimised from controlled combustion (TBDD-equiv. special case due to allocation constraints)
- These species are major constituents of fire gases from flashed-over fires
- NFR TV involved in more fires

Cancer risk
BaP-equiv : TCDD-equiv.

Present Scenario		Future Scenario	
NFR TV	FR TV	NFR TV	FR TV
100 000	30 000	80 000	1 300

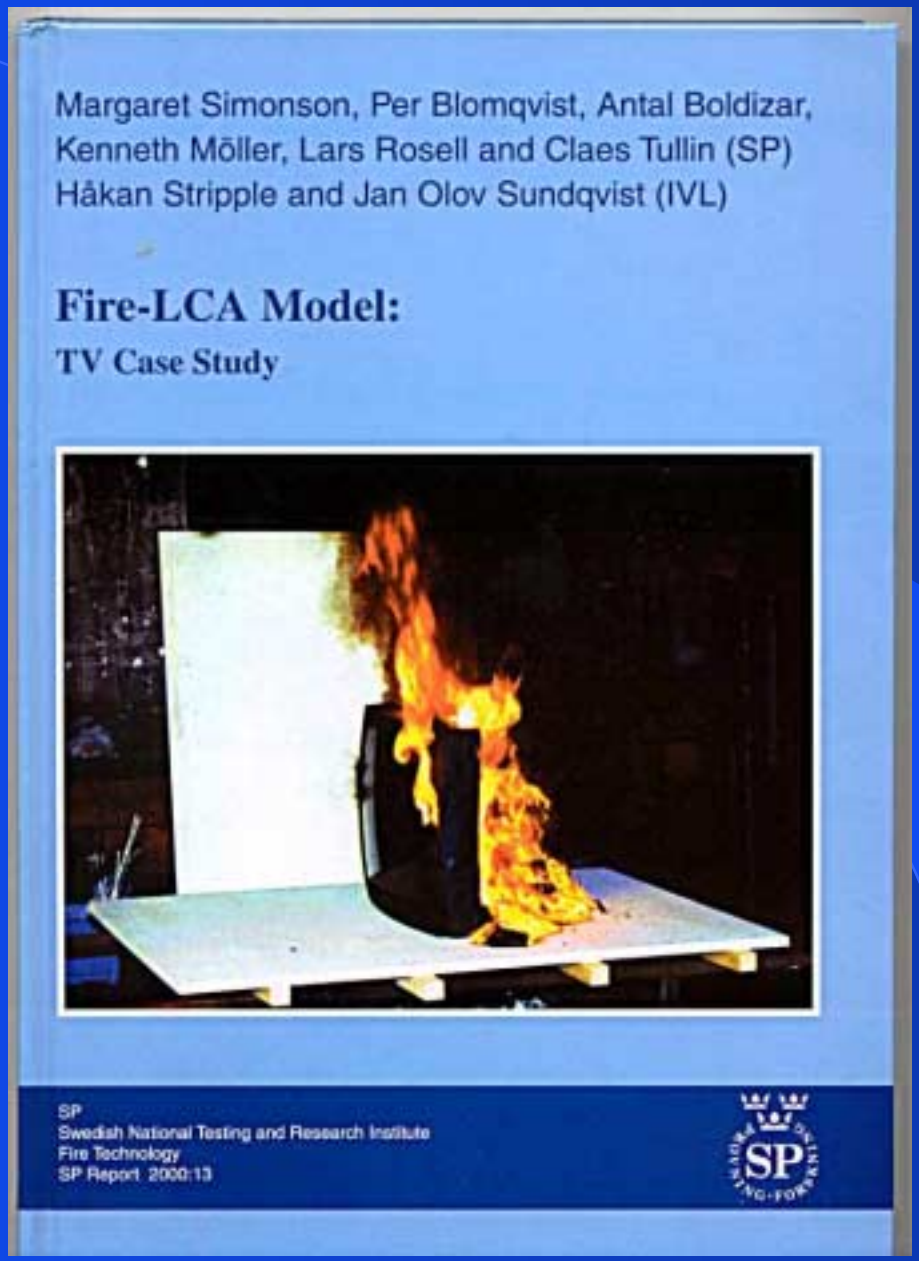
$$\text{Cancer Risk Factor} = \frac{(\text{BaP-equiv.} \times \text{URF}_{\text{BaP}})}{(\text{TCDD-equiv.} \times \text{URF}_{\text{TCDD}})}$$

$$= \frac{\text{PAHのリスク}}{\text{ダイオキシンのリスク}}$$

Conclusions

- Minor energy difference between FR and NFR alternatives
- Fires small source of CO, CO_2, NO_x…
- NFR:FR TV - differences most marked for large organic species
- PAH most significant toxicologically
- Full risk analysis must consider risk for death and injury from fires: 16 dead, 197 injured in Europe each year from TV fires according to Sambrook study (may be ca. 160 dead, 2000 injured)

Fire-LCA TV Case Study




Environmental Awareness
is Increasing

Fires effect the environment