Effects of mitigation policies on future PM emissions from on-road vehicles

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Outline

- **Background**
  - Mitigation and BC reduction
  - Ideal candidates for BC control: diesel vehicles

- **Approach to modeling**
  - Speciated Pollutants Emission Wizard (SPEW)-Trend
  - Fundamental idea of engineering model

- **Definition and mechanics**
  - Scrappage
  - Retrofit

- **Methods**
  - Scenario analysis
  - Monte Carlo simulations

- **Results and conclusion**

Argonne National Laboratory
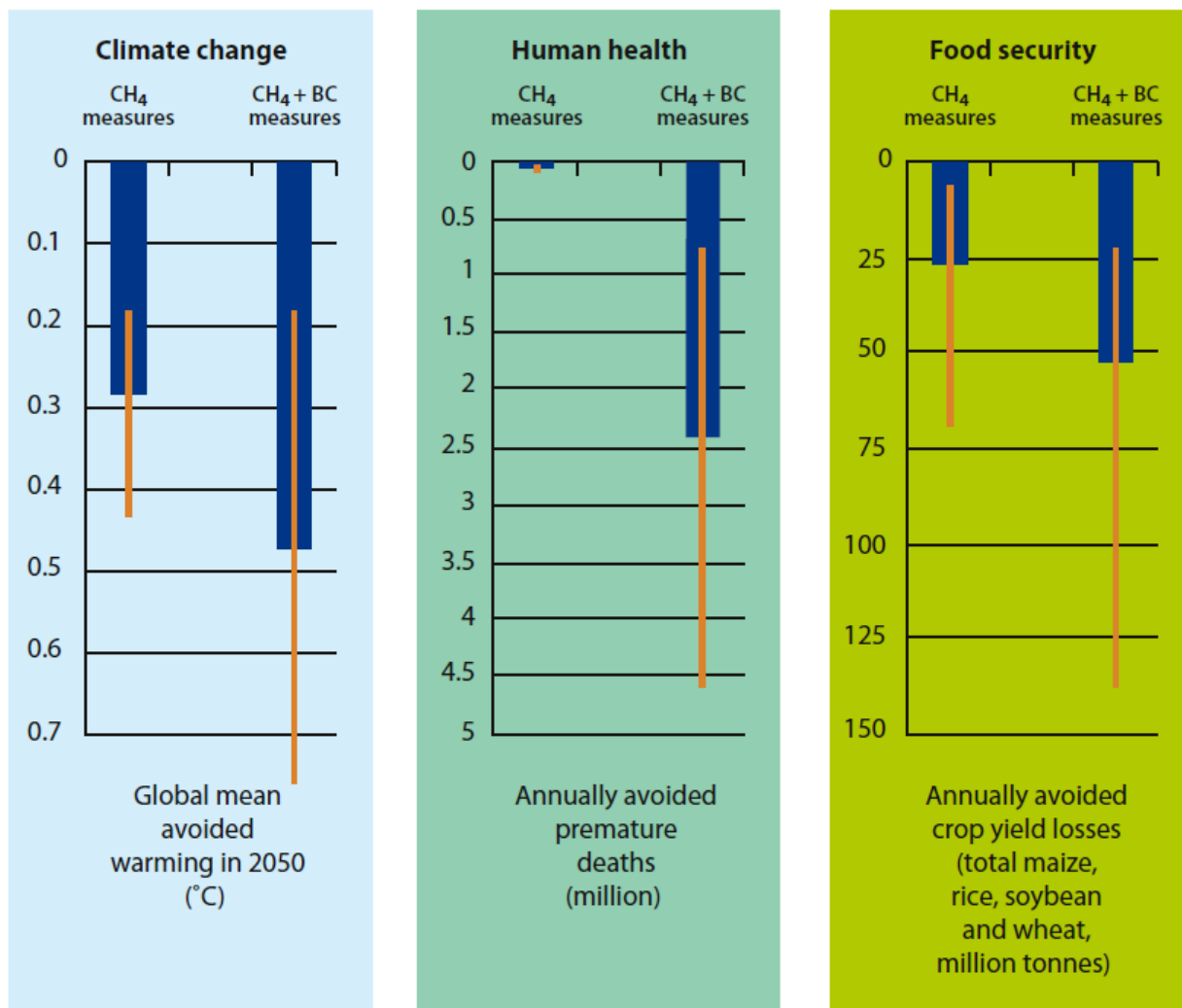
Mitigation and black carbon (BC) reduction

Figure 1. Global benefits from full implementation of the identified measures in 2030 compared to the reference scenario. The climate change benefit is estimated for a given year (2050) and human health and crop benefits are for 2030 and beyond. (UNEP, 2011)

Ideal candidates for BC control: diesel vehicles

- Very low ratio of OC/BC

- Substantial health co-benefits

- Control technology available (PM control programs)
  - Emission standards: all new vehicles
  - Scrappage: diesel and gasoline ⎤
  - Retrofit: diesel ⎦ Existing vehicles

- **However,** deficiency in the determination of emission reduction potential in the future, especially with consideration of uncertainty

Speciated Pollutants Emission Wizard (SPEW)-Trend

Economic Model
(developed by other groups)
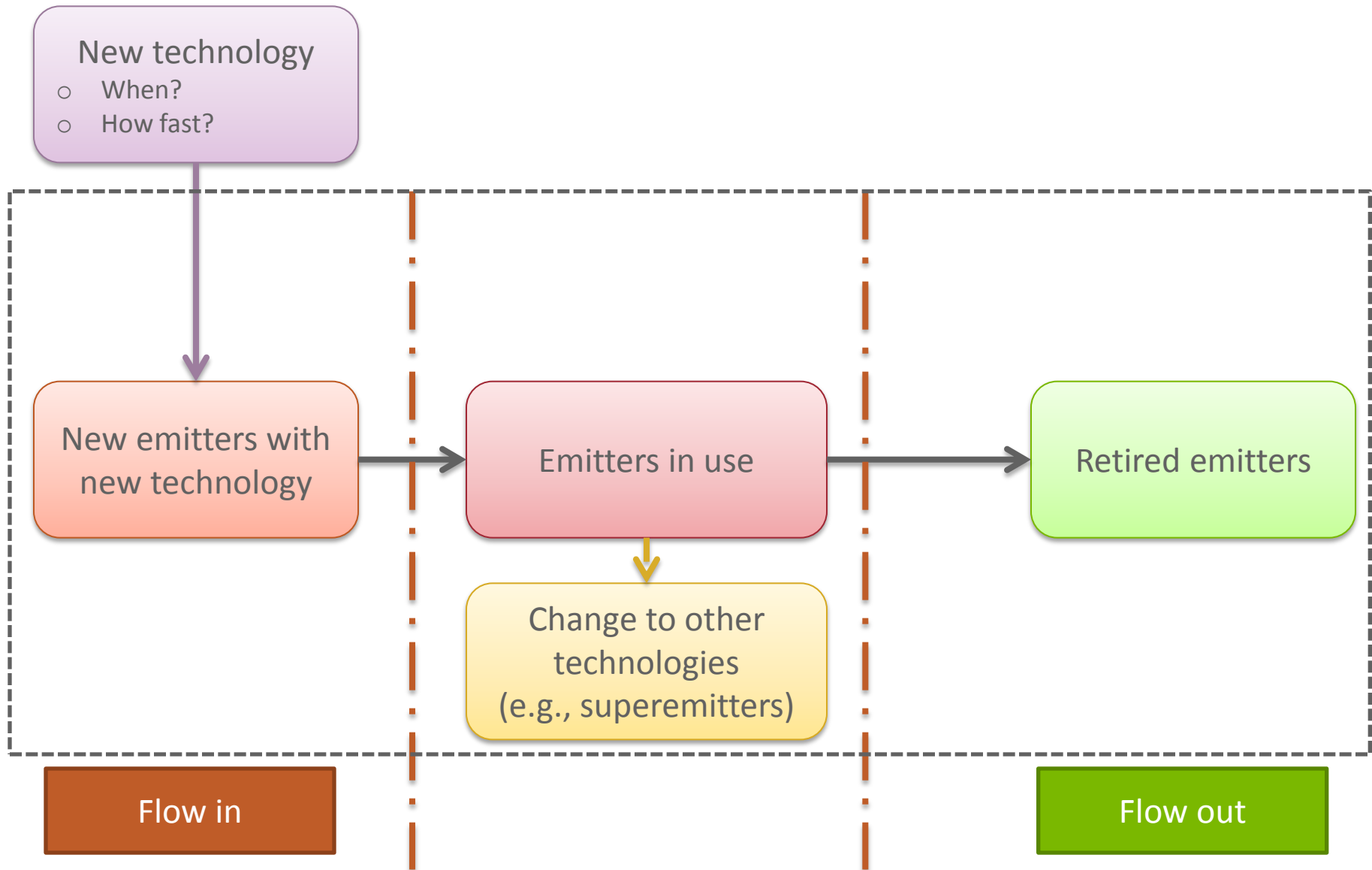
Seeks supply-demand equilibrium among sectors and regions

Engineering Model

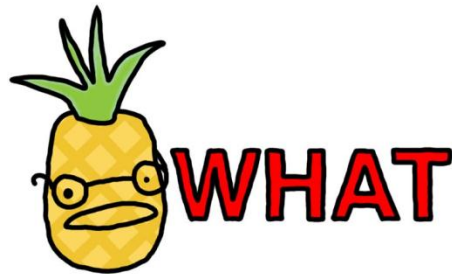Specifies physical components of technological change

Hybridize

- A dynamic technology model developed by Dr. Bond's group at University of Illinois at Urbana-Champaign
  - Driven by activity provided by economic models
  - Based on historical consumer behavior
  - Tabulates dynamic technology splits
  - Flexible and consistent

Fundamental idea of engineering model

New technology
- When?
- How fast?

New emitters with new technology → Emitters in use → Retired emitters

Emitters in use → Change to other technologies (e.g., superemitters)
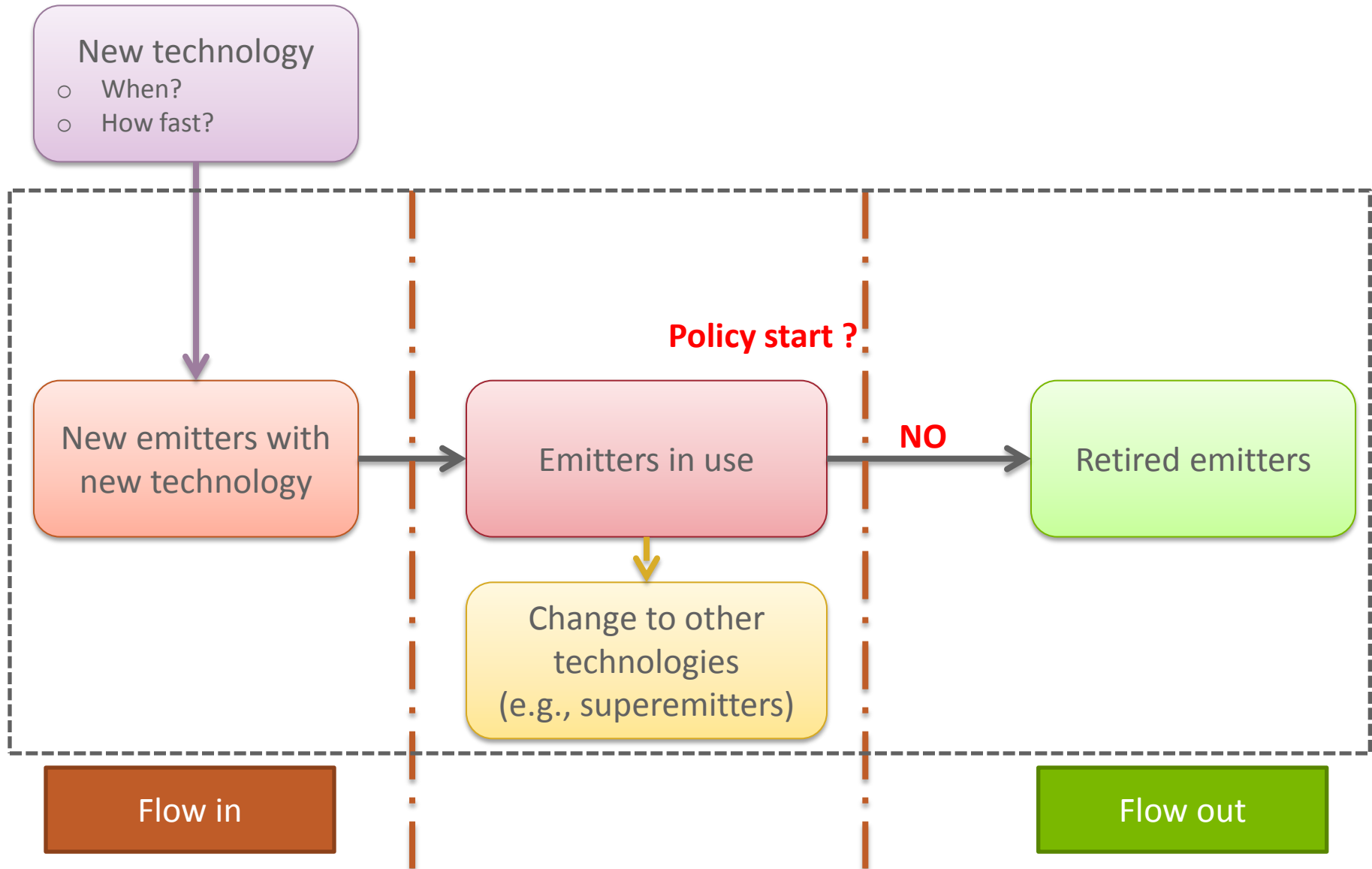
Flow in

Flow out

Scrappage

- Scrappage, or fast scrappage: replacement before their owners would otherwise scrap them

- **Key questions:**

Accelerated retirement rate
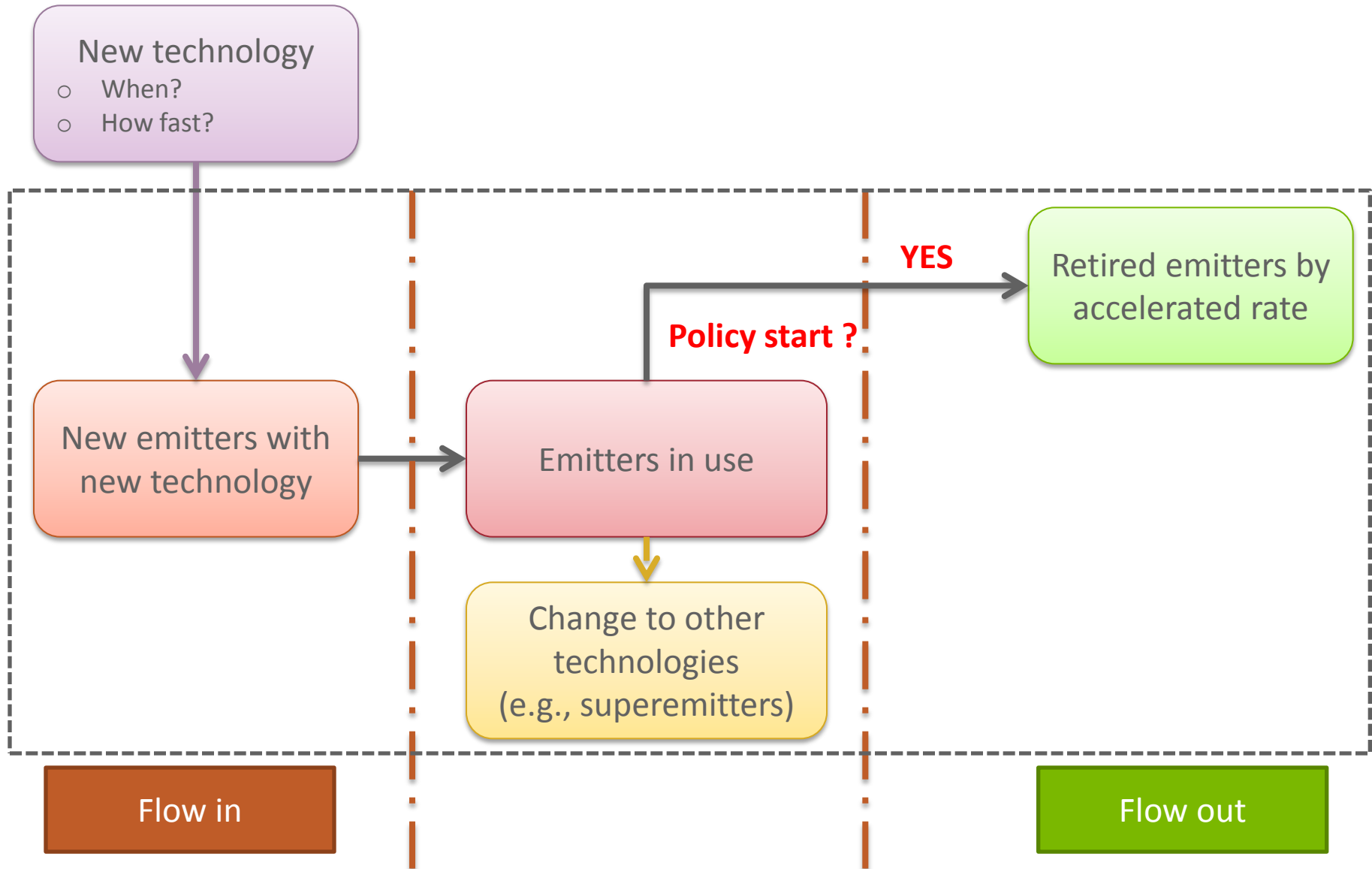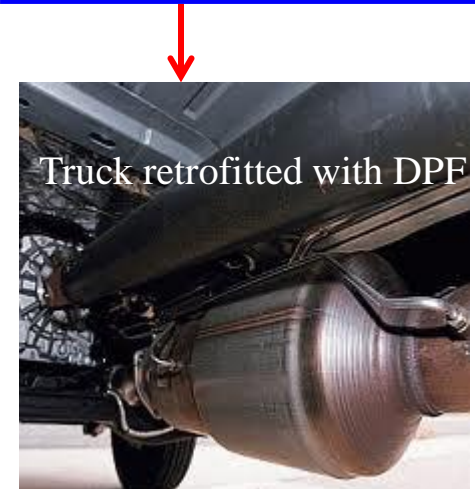
How does scrappage work?

New technology
- When?
- How fast?

New emitters with new technology

Emitters in use

Policy start ?

NO

Retired emitters

Change to other technologies (e.g., superemitters)

Flow in

Flow out

How does scrappage work?

New technology
- When?
- How fast?

New emitters with new technology

Emitters in use

Policy start ?

YES

Retired emitters by accelerated rate

Change to other technologies (e.g., superemitters)

Flow in

Flow out

Retrofit

Diesel Particulate Filter
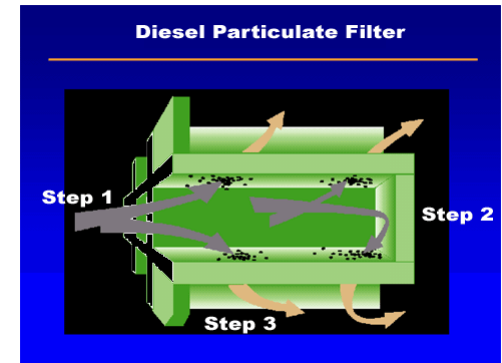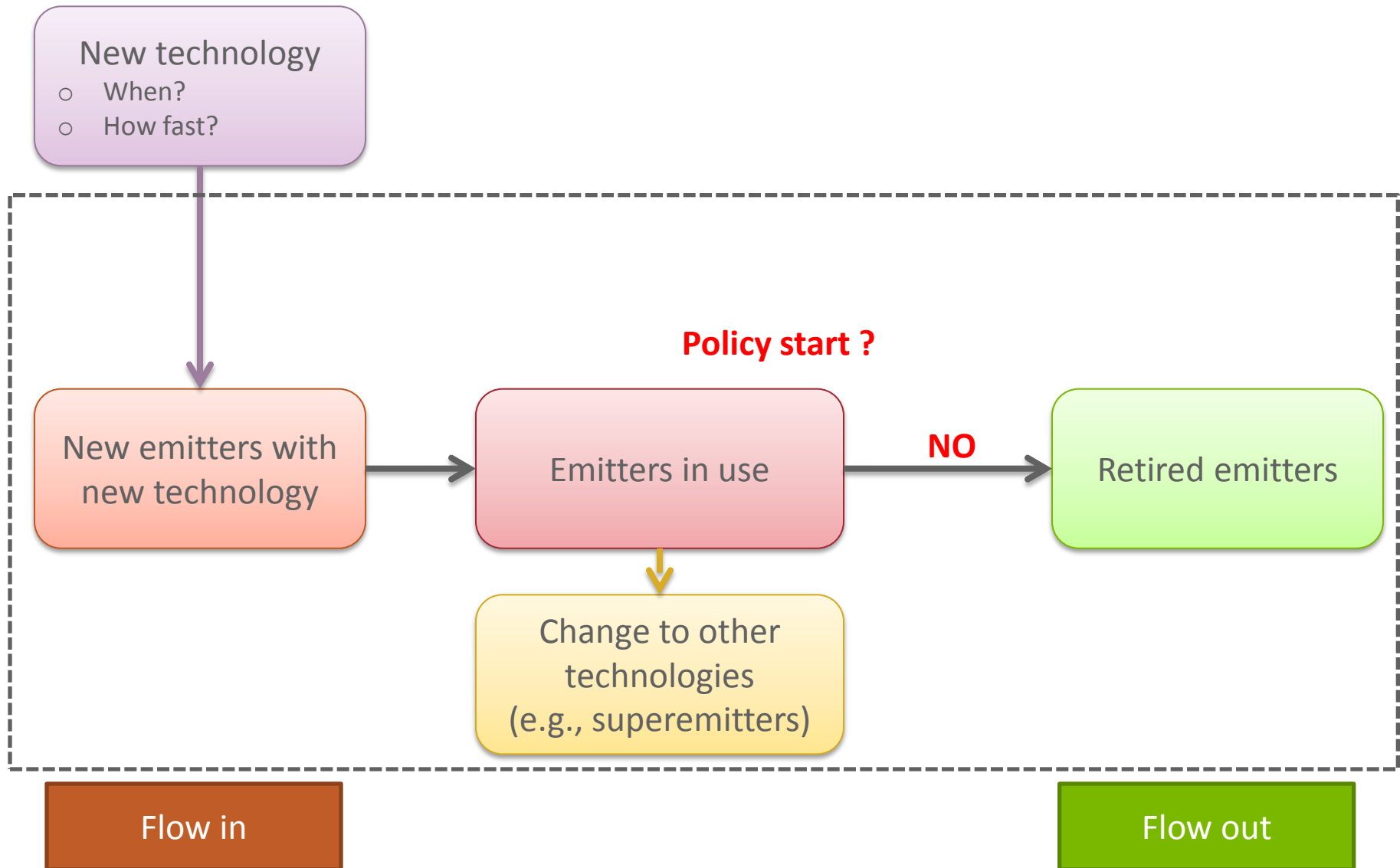
- **Retrofit** : Technology or device applied to an existing diesel vehicle or engine to reduce emissions

  - Diesel particulate filters (DPFs): PM, >90%

- Similar key questions: **What, when and what rate?**

- Additionally: to which technology or emission standard can an old one be retrofitted?

Truck retrofitted with DPF

How clean?

How does retrofit work?

New technology
○ When?
○ How fast?

New emitters with new technology → **Emitters in use** → **Retired emitters**

Policy start ?

NO

Change to other technologies (e.g., superemitters)

Flow in

Flow out

How does retrofit work?

New technology
- ○ When?
- ○ How fast?

New emitters with new technology → Emitters in use

Policy start ?

YES → Retrofit to low-emitting technology

Emitters in use → Retired emitters

Emitters in use → Change to other technologies (e.g., superemitters)

Flow in

Flow out

Methods

- All emission projections are based on A1B scenario

- Scenario analysis
  - Designed policy scenarios (key variables)
  - From most to least aggressive programs (best to worst)

- Monte Carlo simulations (MCS)

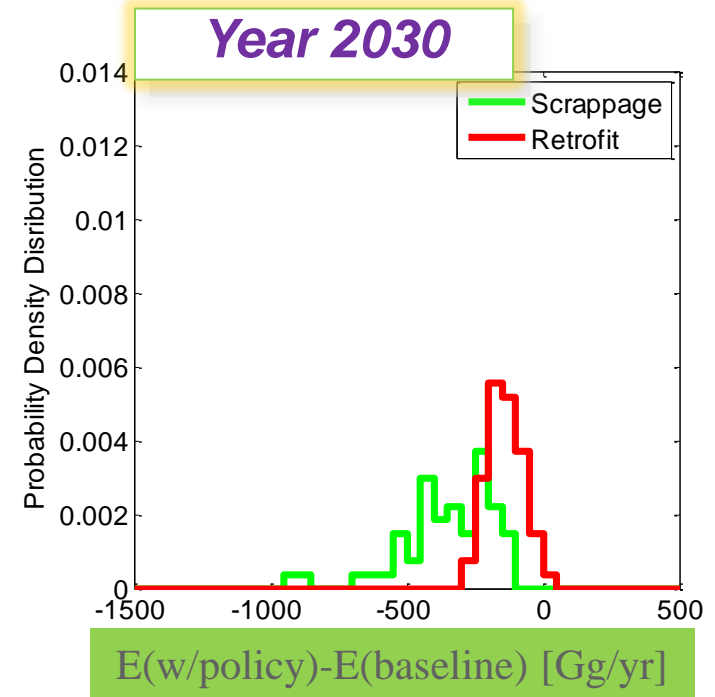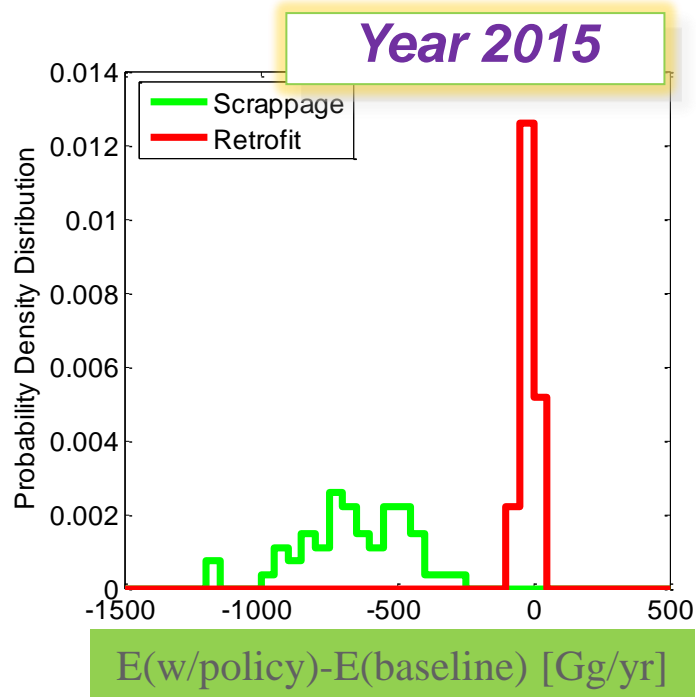| Cases	Parameters setup
Baseline	Replace uncertain variables with probability distributions
Scrappage	Baseline + fixed variables for scrappage program
Retrofit	Baseline + fixed variable for retrofit program

Results from scenario analysis
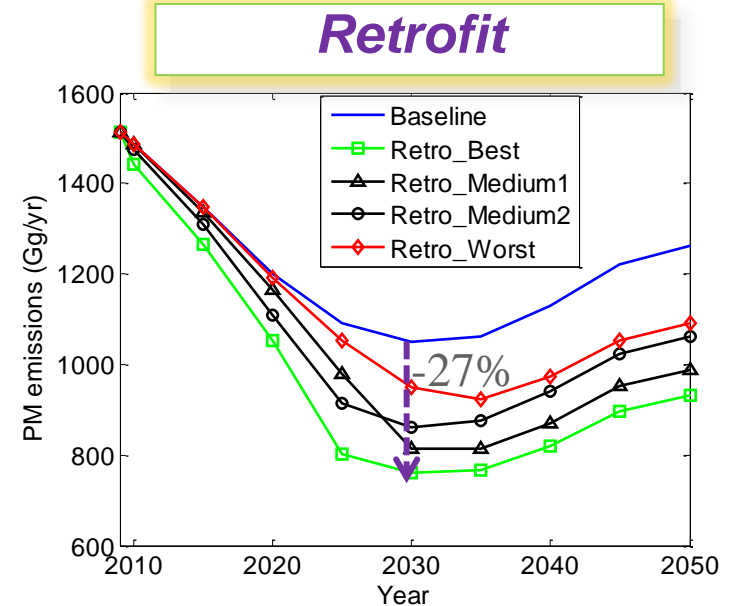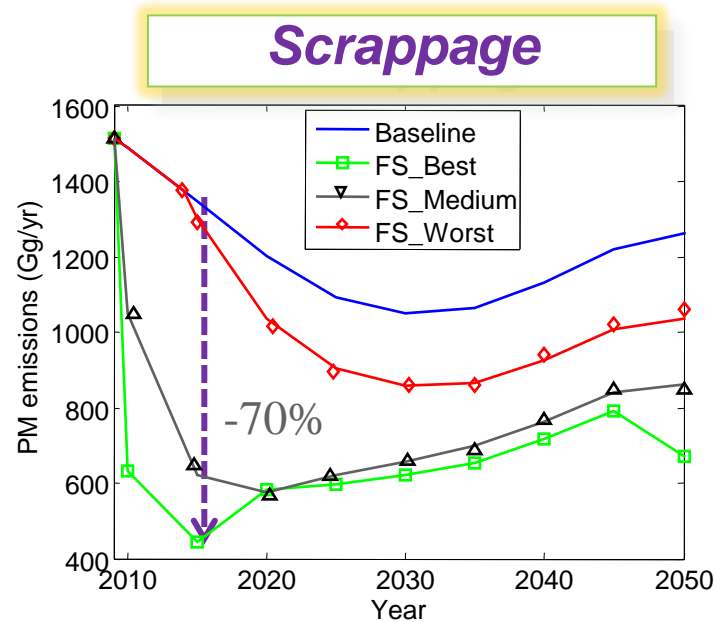
- **Scrappage**: an immediate and higher emission reduction
- **Retrofit**: reduces emissions more in later years when very advanced technology becomes available in most regions
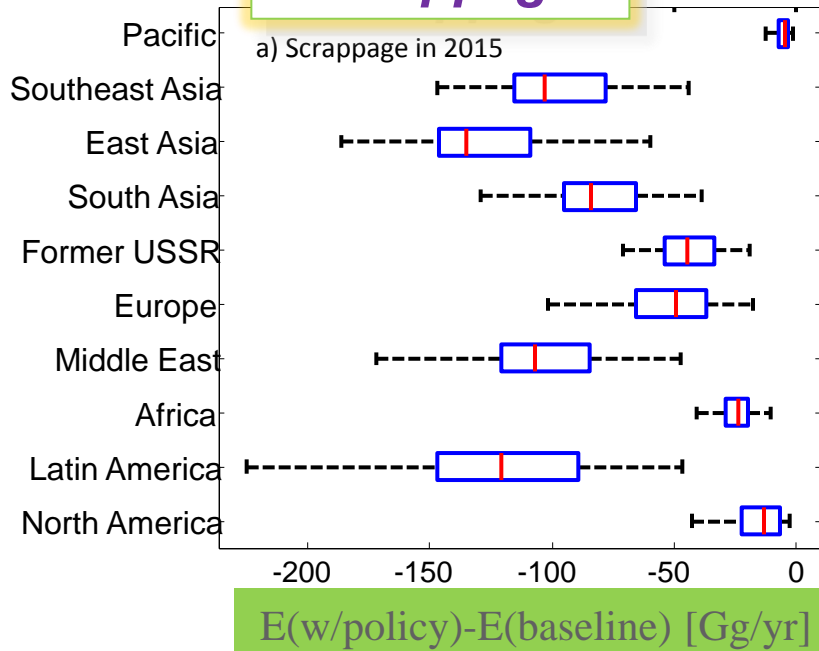
Results from MCS: global emission reductions

Year 2015

Probability Density Distribution vs E(w/policy)-E(baseline) [Gg/yr]

Legend: Scrappage (green), Retrofit (red)

Year 2030

Probability Density Distribution vs E(w/policy)-E(baseline) [Gg/yr]

Legend: Scrappage (green), Retrofit (red)

Policy	Year	90% CI of [E(w/policy)-E(baseline)] [absolute value (Gg/yr)]	90% CI of [E(w/policy)/E(baseline)-1] [relative emission change]
Scrappage	2015	-683 ± 318	-62% to -41%
	2030	-376 ± 285	-49% to -22%
Retrofit	2015	-40 ± 36	-4% to -1%
	2030	-166 ± 114	-23% to -9%
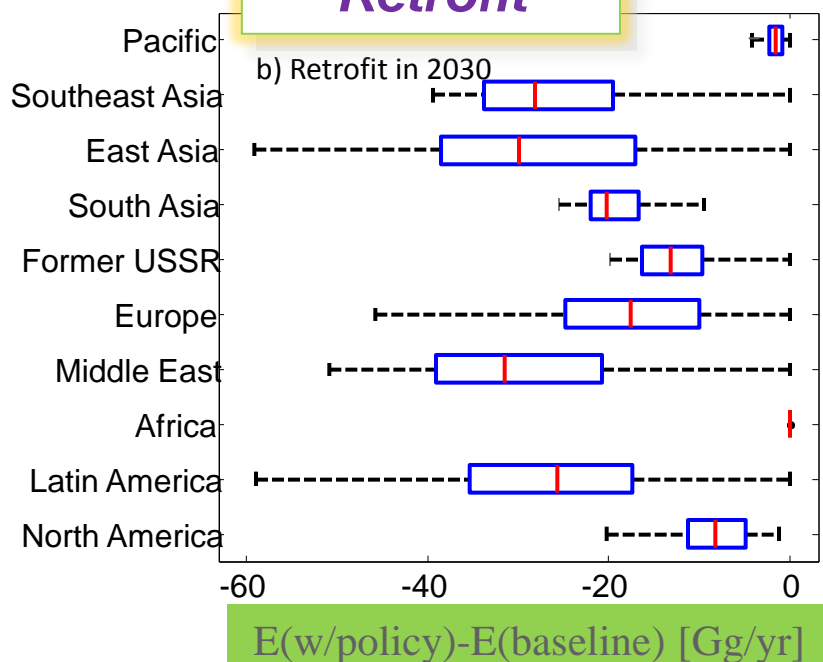
Results from MCS: regional emission reductions

Results from MCS: regional emission reductions

Scrappage

a) Scrappage in 2015

E(w/policy)-E(baseline) [Gg/yr]

Results from MCS: regional emission reductions

Scrappage

a) Scrappage in 2015

Pacific
Southeast Asia
East Asia
South Asia
Former USSR
Europe
Middle East
Africa
Latin America
North America

-200 -150 -100 -50 0

E(w/policy)-E(baseline) [Gg/yr]
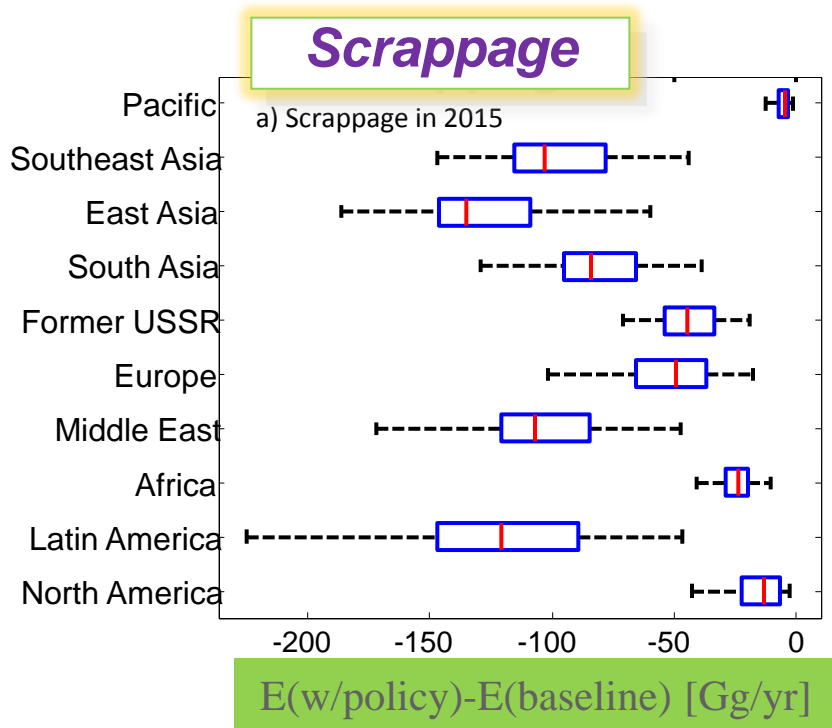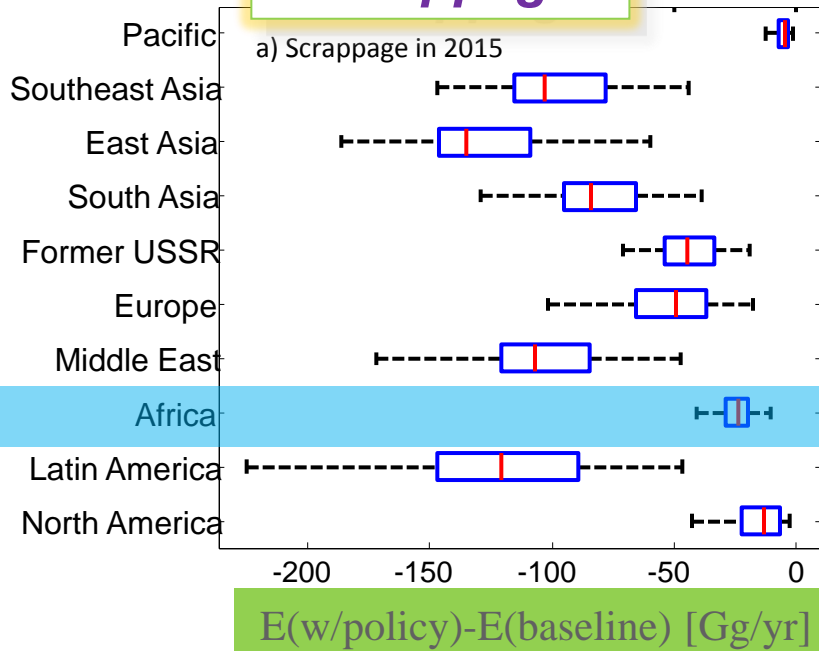
Africa has not implemented advanced emission standards , so there are no cleaner vehicles to replace the old scrapped one

Results from MCS: regional emission reductions

Scrappage

a) Scrappage in 2015

Pacific
Southeast Asia
East Asia
South Asia
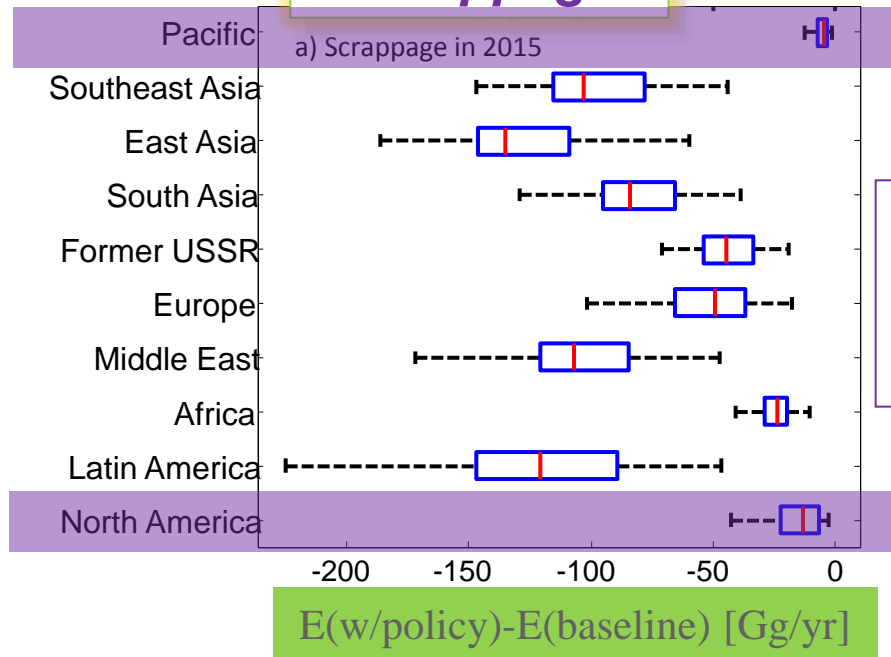Former USSR
Europe
Middle East
Africa
Latin America
North America

-200   -150   -100   -50   0

E(w/policy)-E(baseline) [Gg/yr]
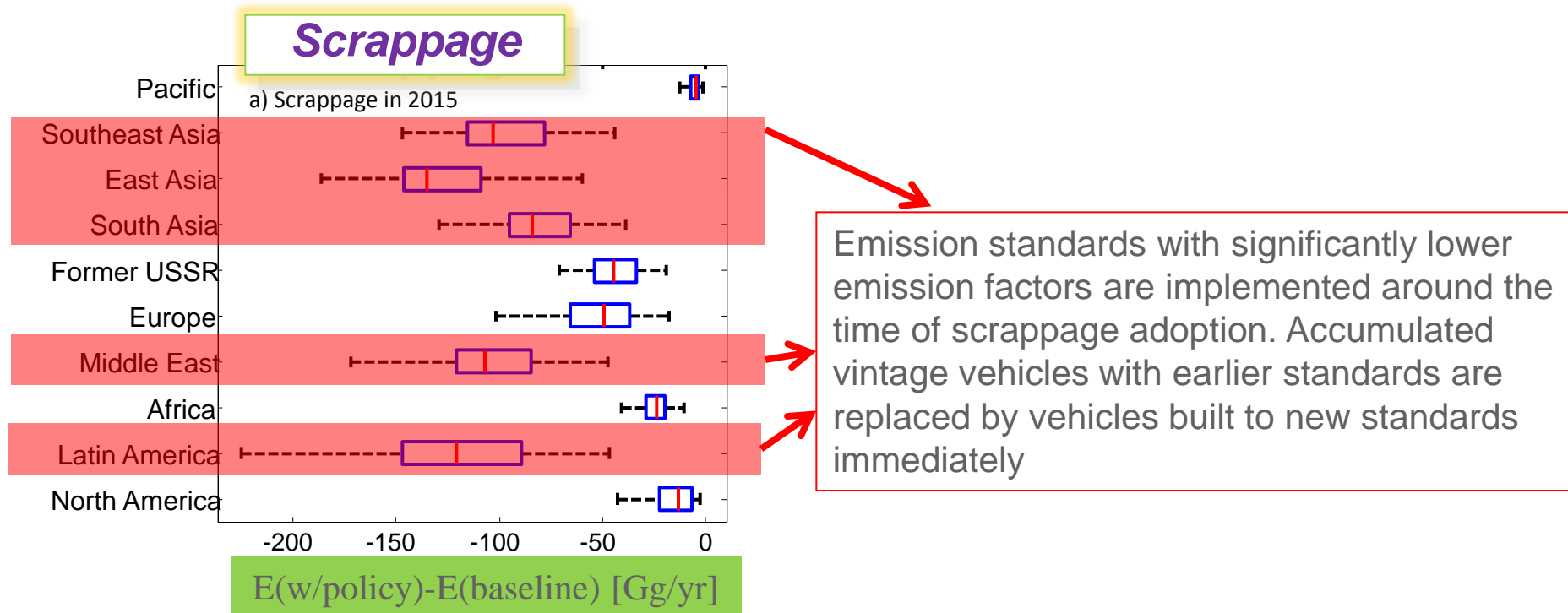
Current emission standards already require low enough emission rates, thus the newly implemented ones reduce emissions insignificantly

Results from MCS: regional emission reductions

Scrappage

a) Scrappage in 2015

Regions (top to bottom): Pacific, Southeast Asia, East Asia, South Asia, Former USSR, Europe, Middle East, Africa, Latin America, North America

X-axis: E(w/policy)-E(baseline) [Gg/yr], values -200, -150, -100, -50, 0

Emission standards with significantly lower emission factors are implemented around the time of scrappage adoption. Accumulated vintage vehicles with earlier standards are replaced by vehicles built to new standards immediately

- **Most emission reductions occur in regions where**
  - Policies are implemented in conjunction with the introduction of new technologies with significantly lower emissions
  - Retirement rate is slower, so old vehicles have accumulated and superemitter fraction is high

Conclusions

- Scrappage and retrofit policies have high potential to reduce emissions

- A 90% confidence interval of global emission reductions in 2030 is
    - 22% to 49% by scrappage
    - 9% to 23% by retrofit

- More emission reductions occur in regions where
    - significantly cleaner standards are implemented simultaneously
    - retirement rate is slower and old vehicles can be accumulated
    - the superemitter fraction is high

More information

- Yan. F, E. Winijkul, S. Jung, T. C. Bond and D. G. Streets (2011), **Global emission projections of particulate matter: I. Exhaust emissions from on-road vehicles,** Volume 45, Issue 28, Pages 4830–4844

- Yan. F, E. Winijkul, T.C. Bond, and D. G. Streets, **Global emission projections of particulate matter: II. Uncertainty analysis for on-road vehicles exhaust emission** (ready to submit)

- Winijkul, E., F. Yan, and T.C. Bond, **Current and future global diesel emission from non-road Equipment** (ready to submit)

Acknowledgements

Thank you☺
Questions?