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Scenarios for regional passenger car use and their CO_2 emissions – The potential of technological innovations

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International Energy Workshop - IEW 2011
6-8 July 2011 Stanford University
Transportation Modeling:
Emissions Mitigation

Outline

Introduction: Why to address global emissions from regional passenger car use?

Methodology: multi-model approach to car stocks and CO_2 emissions scenarios

Scenario results: car stocks (global/regionalized)

Scenario results: CO_2 emissions scenarios and impacts of technological innovations in passenger cars from fuel efficiency and biofuel use

Conclusions

Intro I: Passenger cars and climate change mitigation

- Forecasting growth patterns in passenger car stocks is an essential step to **assessing mitigation potentials of technological change** on energy use and CO_2 emissions.

  Main strategies to reduce emissions from passenger car use:
  - fuel efficiency of car fleets
  - renewable energy [biofuels, electricity from renewable sources]
  - behavioral change [shift modal split - not addressed here]

- Given the **necessity to reduce GHG emissions** in order to prevent dangerous anthropogenic interference with the climate system, the **transport sector has to be addressed** because

  1) worldwide transport CO_2 **emissions are (still) on the rise** [+ 45% 1990-2008] and account for 23% of global CO_2 emissions

  2) other energy consuming sectors cannot compensate for transport related emissions growth

Intro II: Regionally distinct growth patterns

- **Growth in transport CO_2 emissions** from 1990 - 2008

  Annex-I parties: +16.4% growth in transport CO_2

  Worldwide: +44.1% growth in CO_2

  (IEA-Database)

- Increase in transport-related emissions was **particularly strong in economies in transition and developing countries.**

- **Future Dynamics are expected to be high**, e.g.
  New Policy Scenario of IEA projects global transport energy demand to grow on average by 1.3% p.a. from 2008 – 2035 (~+33%).

- All of the **growth comes from non-OECD regions** and inter-regional bunkers.

- Thus, the **mitigation potential** is especially **high in economies in transition** as new passenger cars becoming part of the vehicle stock ideally show high fuel efficiencies.

Intro III: Idea - sector-wide efficiency standards

- Passenger car sector offers a good opportunity for implementing **sector-wide energy efficiency standards** as pursued e.g. by the USA and the EU.
- **Sectoral approach to emissions abatement** could be interesting and effective due to fairly limited number of actors.
- Quantifying long term **baseline and mitigation scenarios of passenger car use emissions** is essential in order to develop roadmaps for technological innovations

Methodology: Assumptions and modeling approach

- **Regionalized multi-model approach:**

  The regionalization of car stock projections allows us to discern **different patterns** in the **level and dynamics of car fleet** developments accounting for specific **historical and geographical trends**. These may point towards region-specific mitigation strategies.

  The **multi-model approach** accounts for **uncertainty** in the **long-term projection** of car fleets (until 2050).

- **Main hypothesis underlying the projections:**
  Preferences for purchasing cars are similar across cultures and nations. Demand for cars is largely determined by disposable income. The average per capita car stock of a regional cluster is modeled by concept of representative consumer.

Three methodologies to project regional car stock growth until 2050

1) **Consumer demand model based on utility maximization**
2) Non-linear regression model based on logistic Gompertz function
3) Panel regression model of income elasticity of car demand

ad 1)

$$X_{t,r} = \beta_{X_{t,r}} \frac{y_{t,r} - \gamma \cdot p_{g_{t,r}}}{p_{X_{t,r}}}$$

X : car stock

y : average disposable income

β_X : marginal budget share for car stock

p : price

γ : subsistence level of demand

t : time index $\quad$ r : regional index

Three methodologies to project regional car stock growth until 2050

1) Consumer demand model based on utility maximization
2) **Non-linear regression model based on logistic Gompertz function**
3) **Panel regression model of income elasticity of car demand**

ad 2)

$$X_{t,r} = \kappa \cdot e^{\alpha \cdot e^{\beta_r \cdot y_{t,r}}}$$

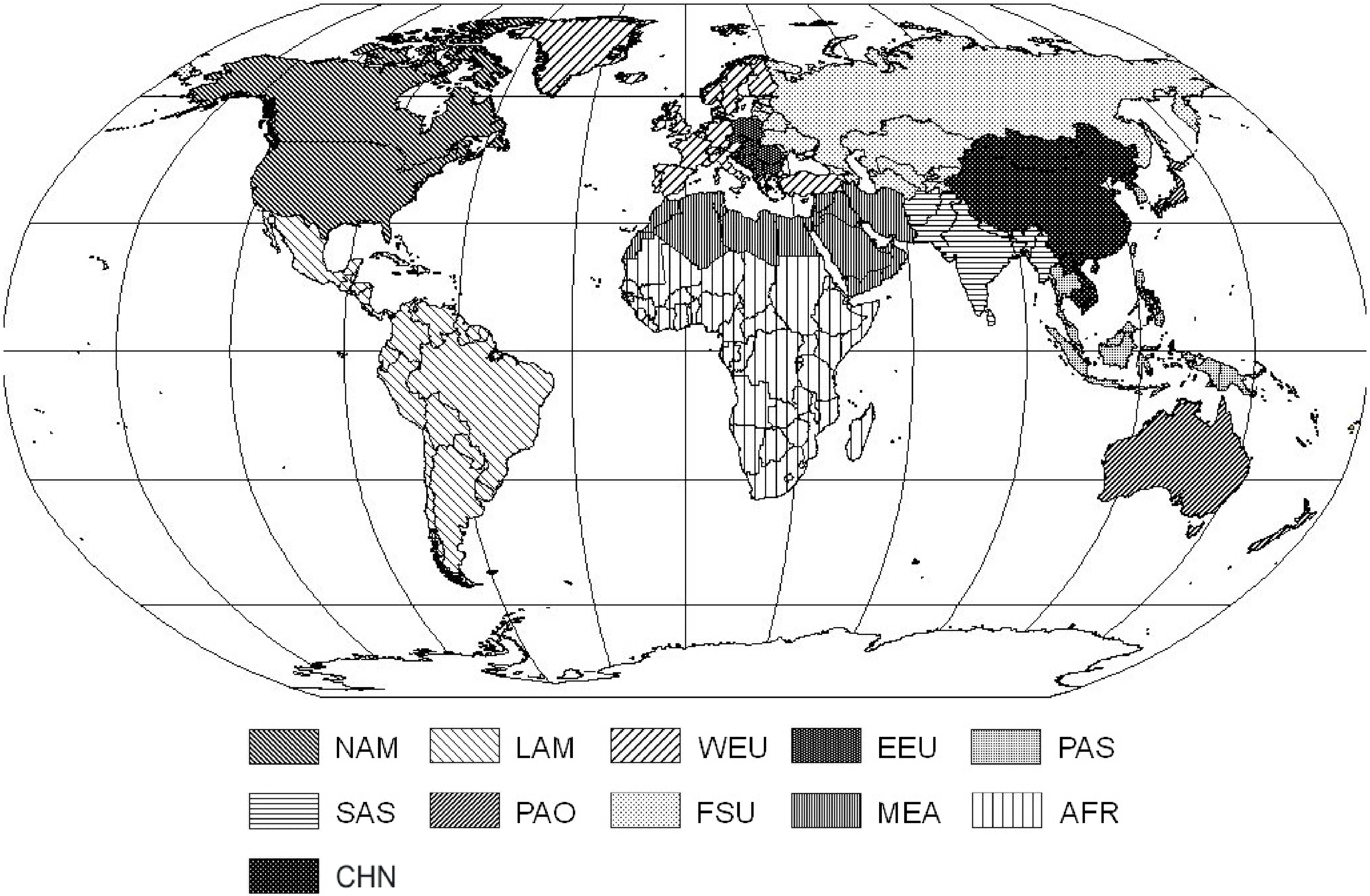
$\alpha, \beta_r < 0$ κ: satiation level

ad 3)

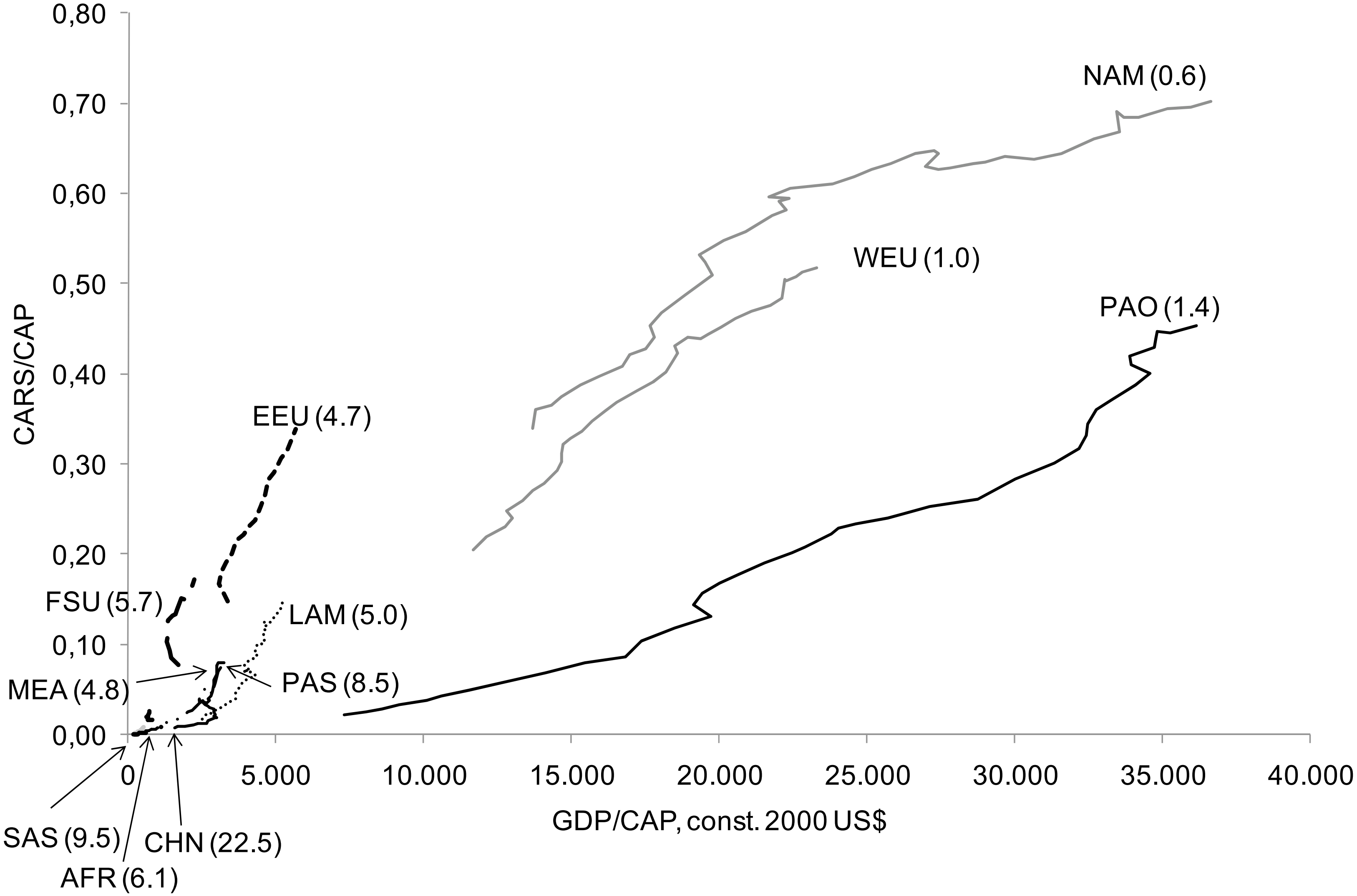
$$\log\left(\frac{X_{t,r}}{1 - X_{t,r}}\right) = \alpha + \mu \cdot y_{t,r} + \epsilon_{t,r}$$

μ : estimate of income elasticity

Data and regional scope



Per capita car stock vs. per capita income 1960 - 2006



Source: Meyer et al. (2011): DOI: 10.1016/j.enpol.2011.01.043

Region	Obs.	Years	Cars per capita		Income per capita	
			From	To	From	To
Africa	26	1981-2006	0.02	0.03	792.7	724.2
China	29	1978-2006	0.00	0.02	164.9	1597.8
Eastern European Union	17	1990-2006	0.15	0.34	3350.0	5667.6
Former Soviet Union	14	1993-2006	0.08	0.17	1679.9	2228.5
Latin America	43	1964-2006	0.02	0.14	2478.5	5146.6
Middle East North Africa	44	1961-2004	0.01	0.08	557.1	3226.6
North America	47	1960-2006	0.34	0.70	13665.7	36621.6
Pacific Asia	44	1960-2003	0.00	0.07	415.9	3143.9
Pacific Asia OECD	45	1960-2004	0.02	0.45	7300.8	36120.9
South Asia	43	1961-2003	0.00	0.01	183.8	511.4
Western European Union	36	1971-2006	0.21	0.52	11664.9	23292.0

Source: Meyer et al. (2011): DOI: 10.1016/j.enpol.2011.01.043

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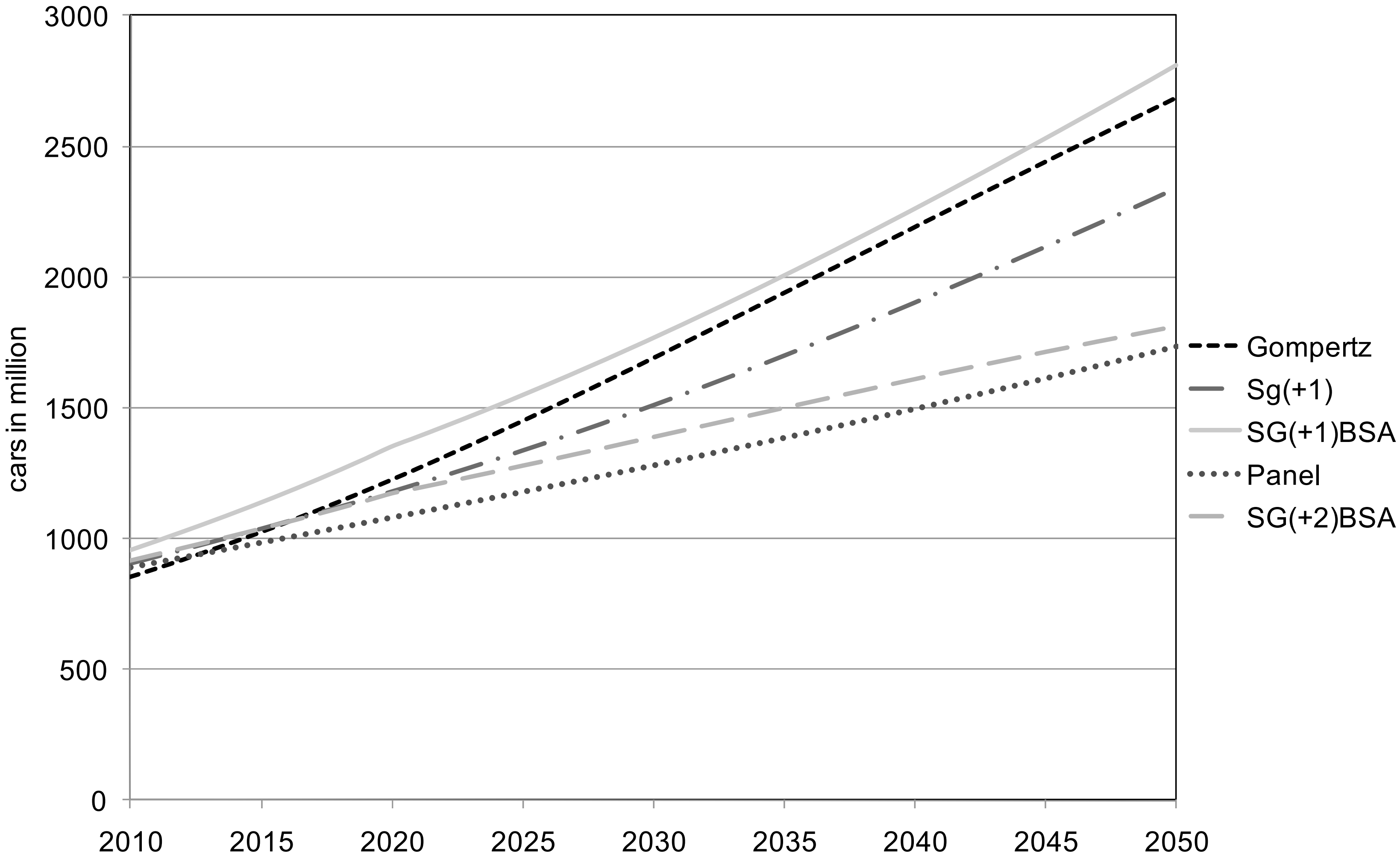
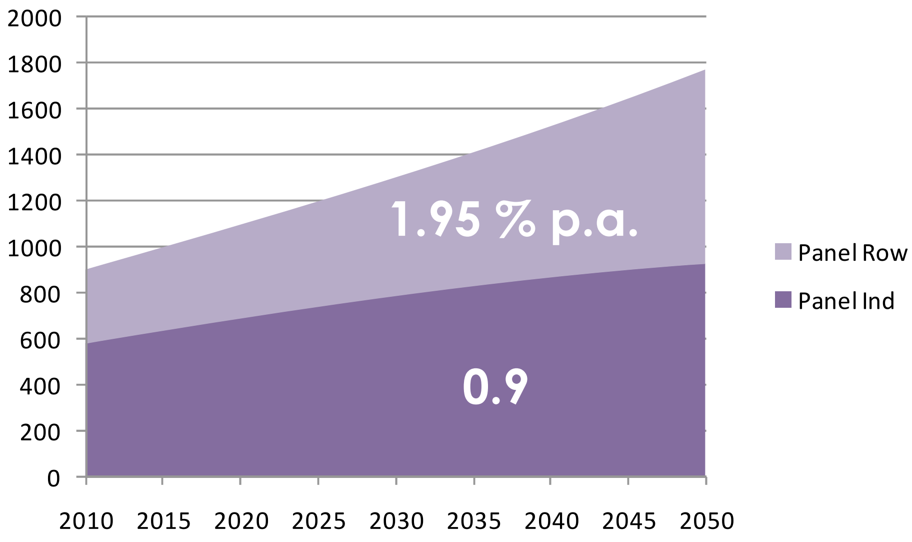
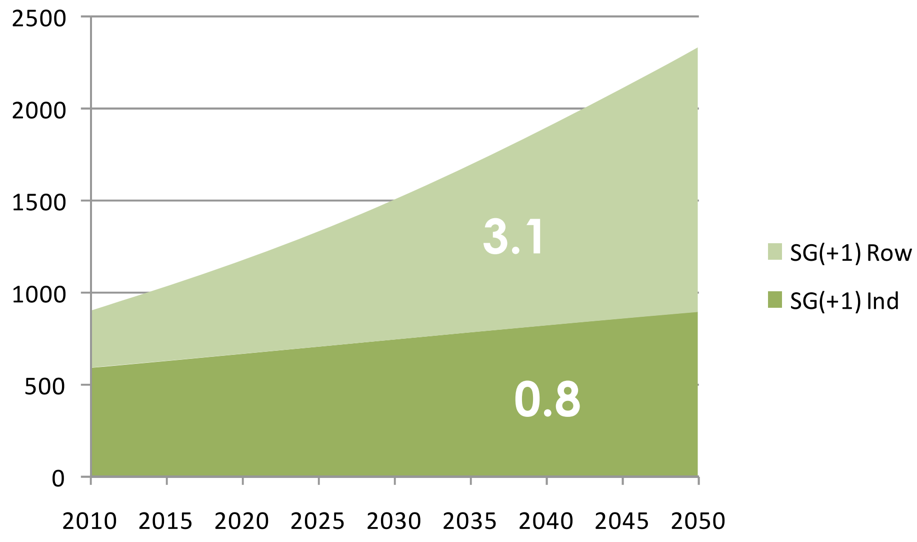
Scenario results: multi-model car stock projections

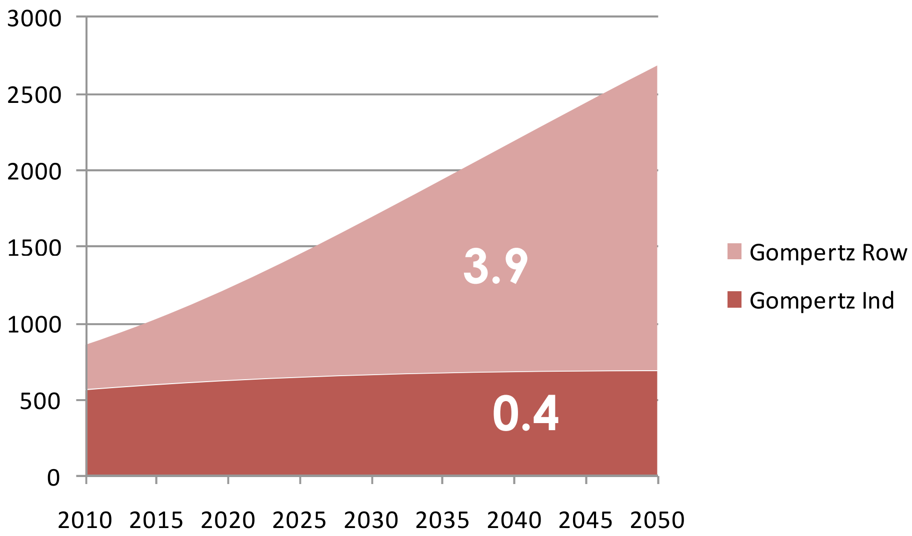


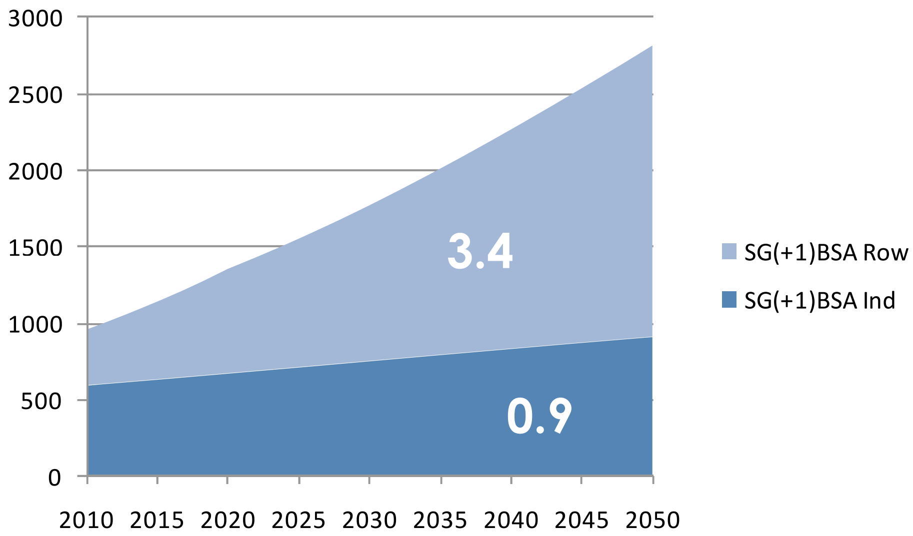
Source: Meyer et al. (2011): DOI: 10.1016/j.enpol.2011.01.043

Scenario results: car stocks - industrialized countries vs Row









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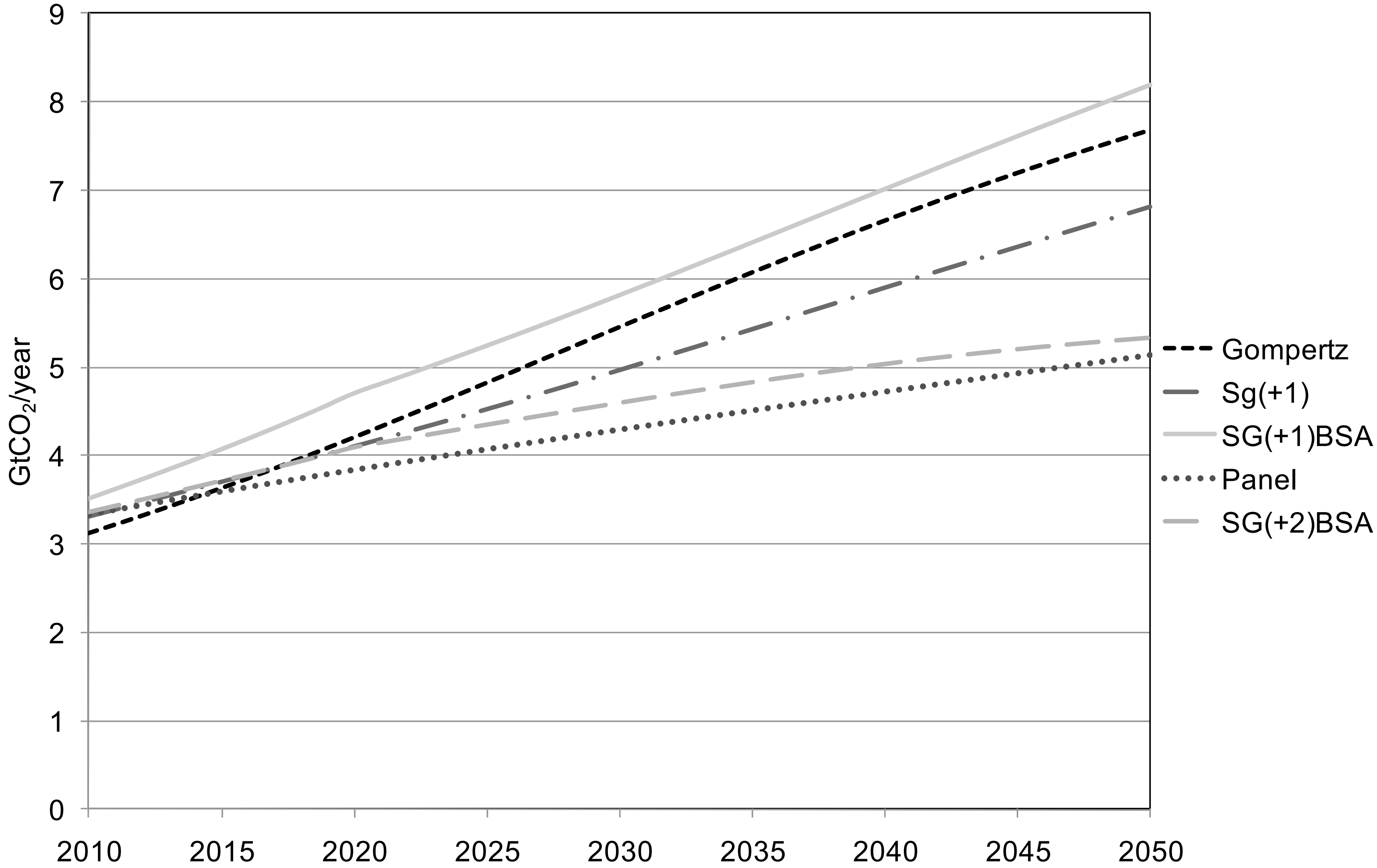
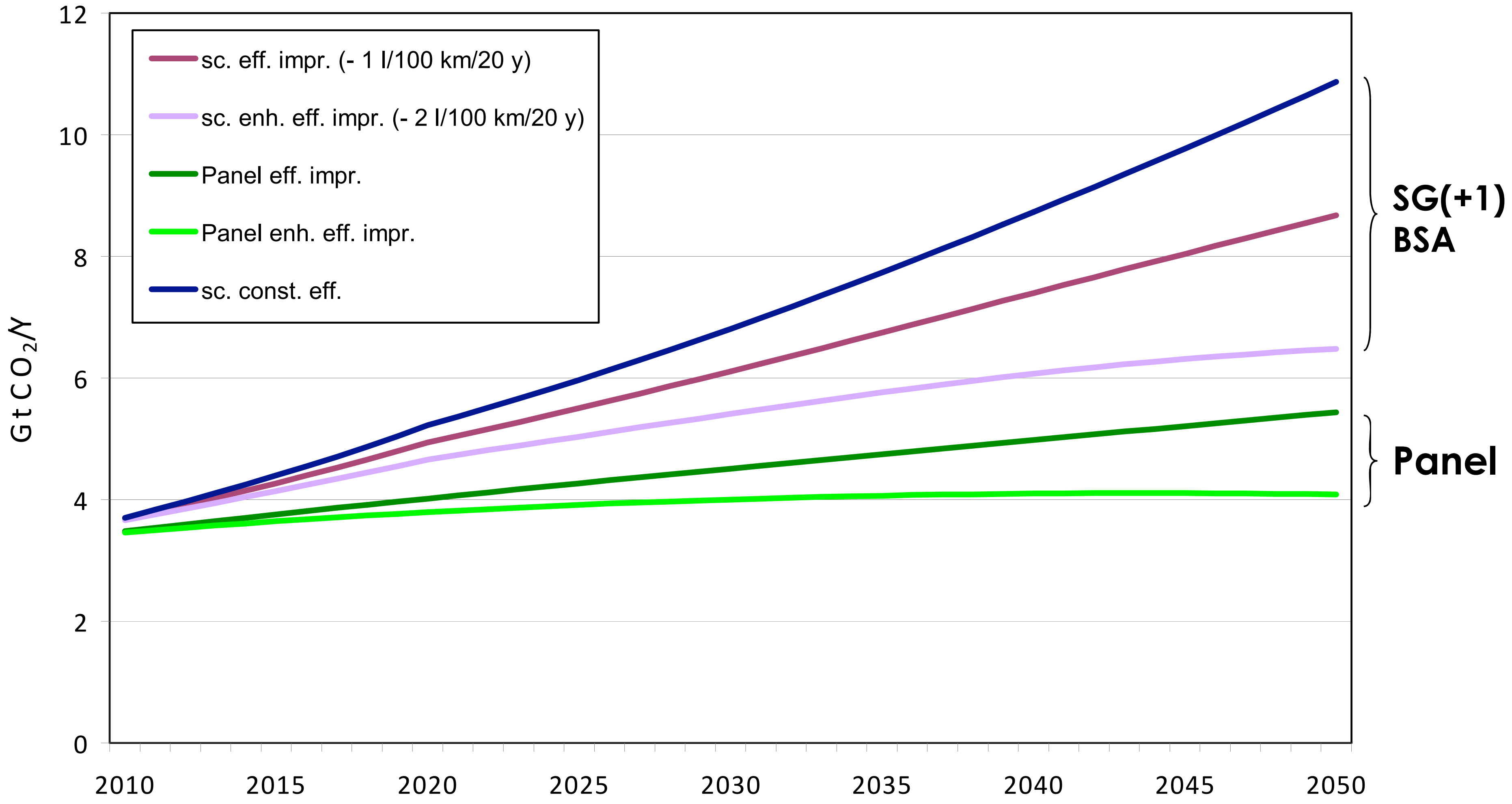
Baseline scenario results: CO_2 emissions scenarios



Source: Meyer et al. (2011): DOI: 10.1016/j.enpol.2011.01.043

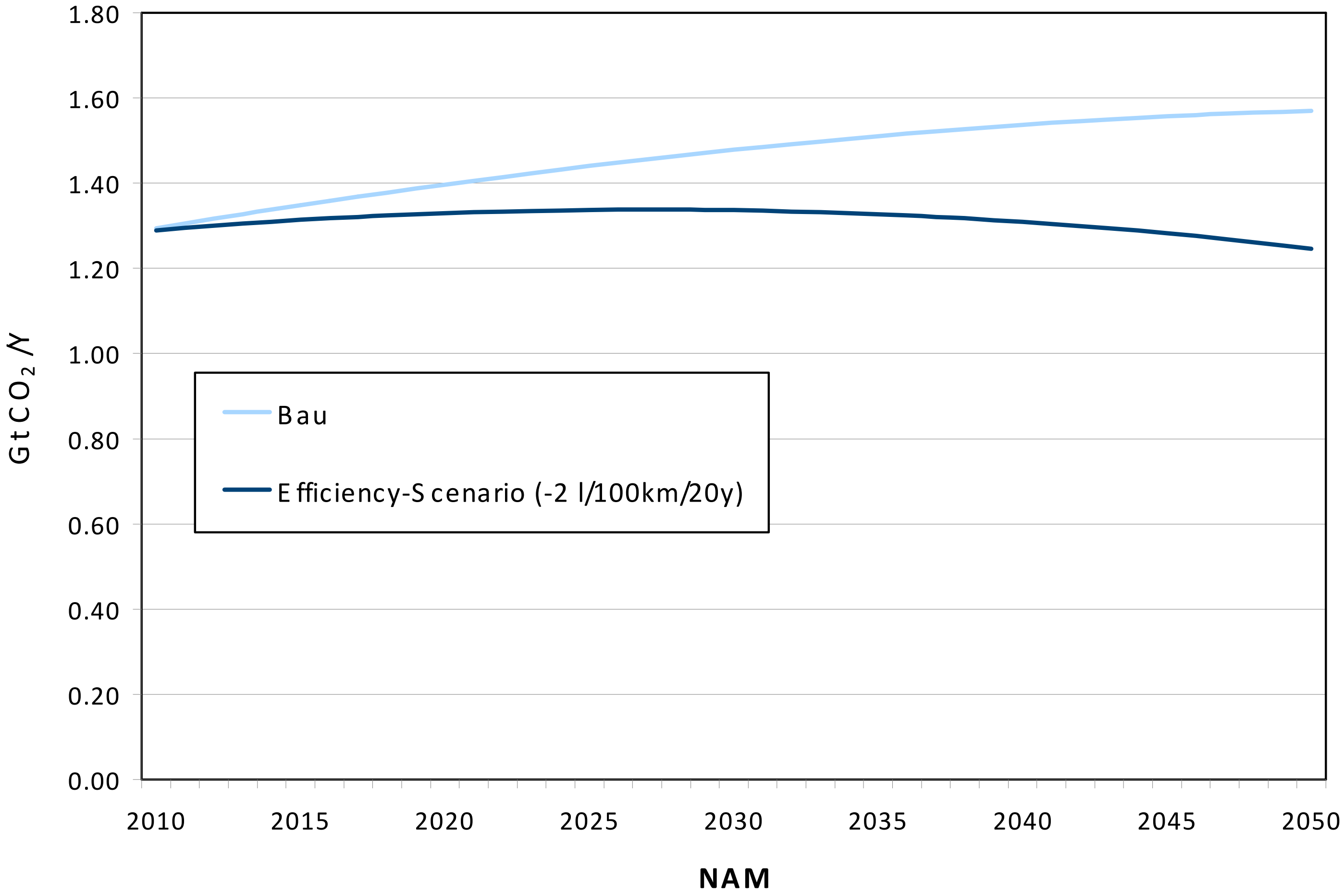
Mitigation scenarios: enhanced fuel efficiency improvements



Source: own calculation

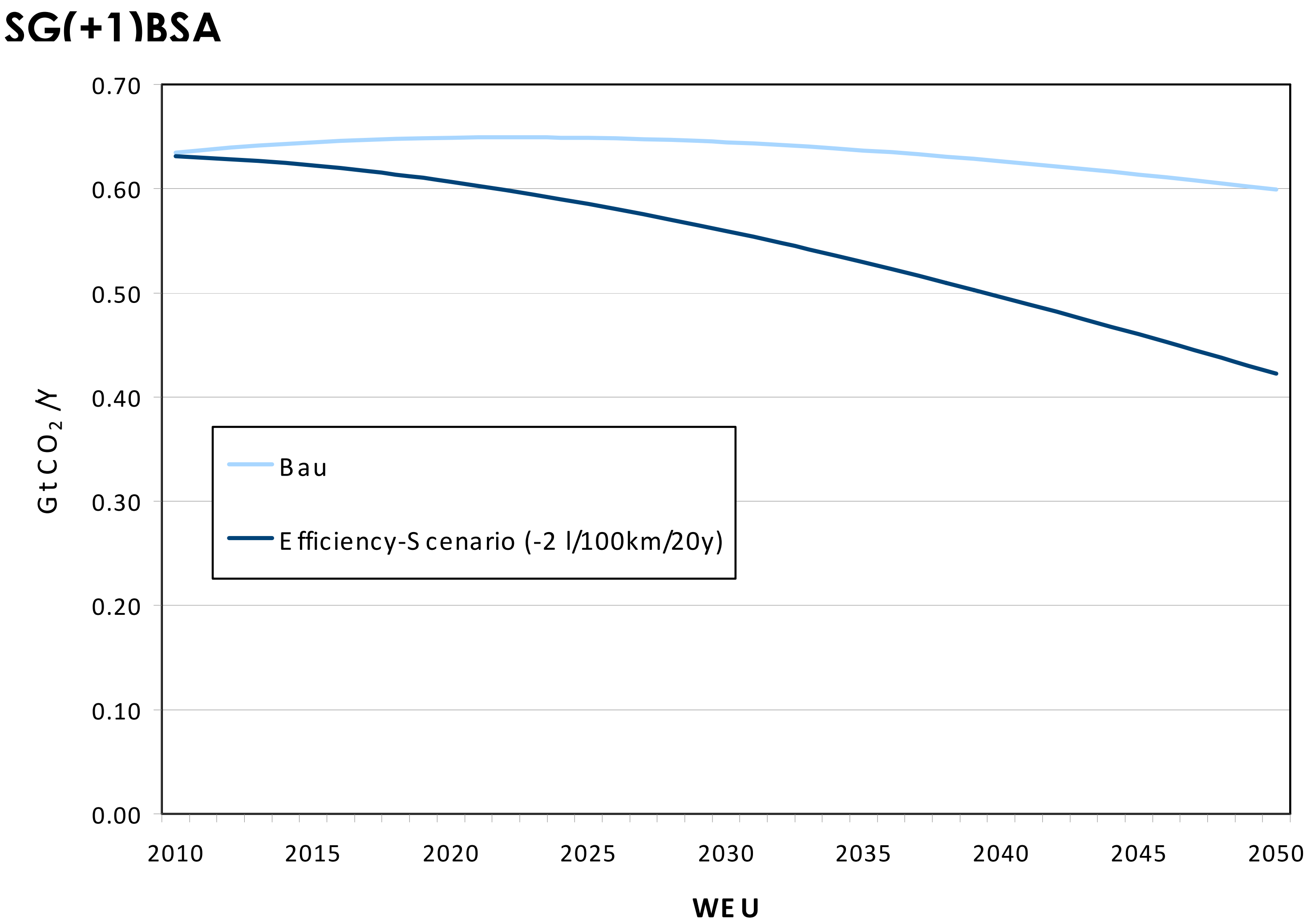
Absolute reduction in emissions from mitigation scenario enhanced fuel efficiency in NAM

SG(+1)BSA



Source: own calculation

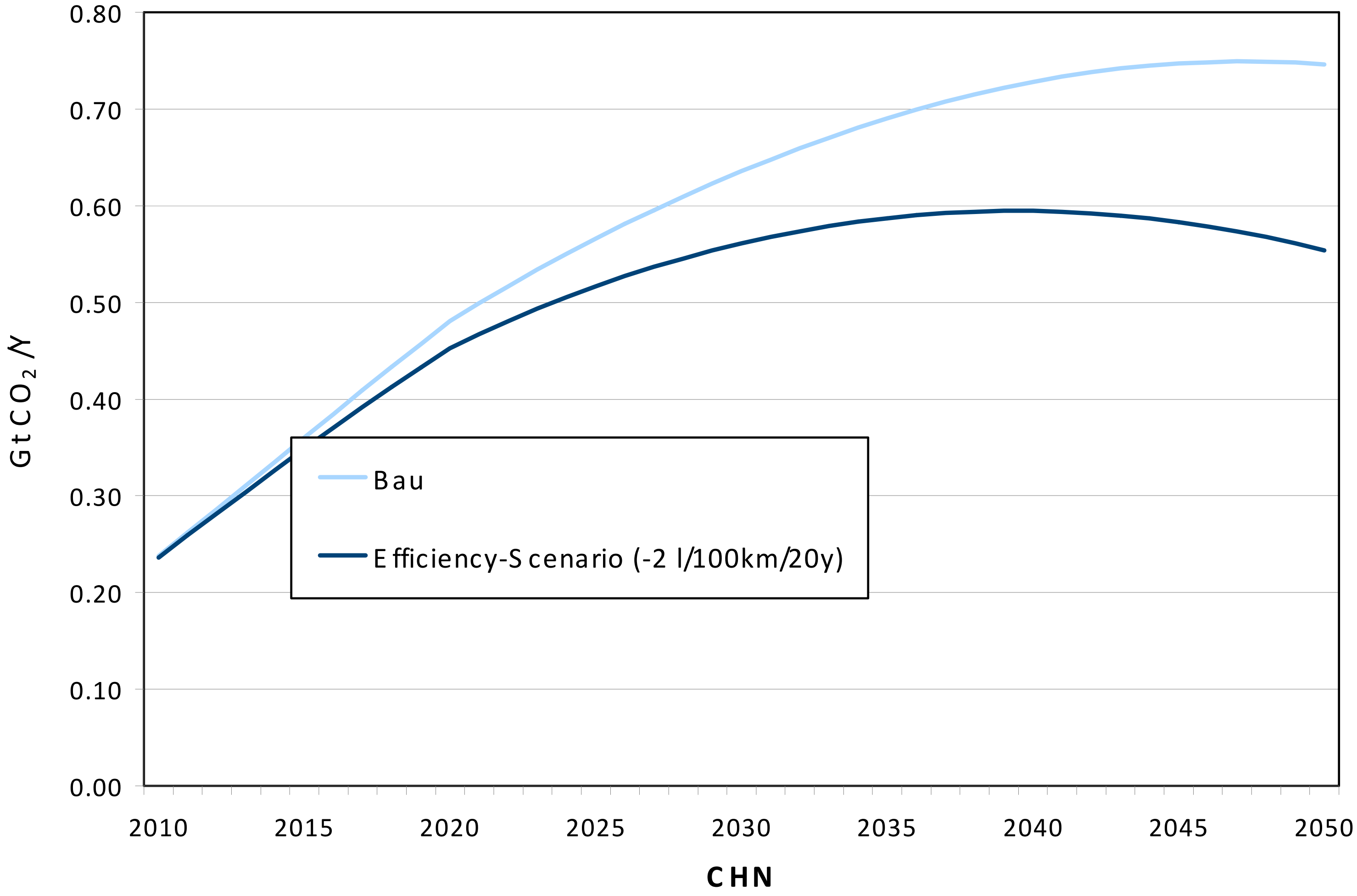
Absolute reduction in emissions from mitigation scenario enhanced fuel efficiency in WEU



Source: own calculation

Relative reduction in emissions from mitigation scenario enhanced fuel efficiency in CHN

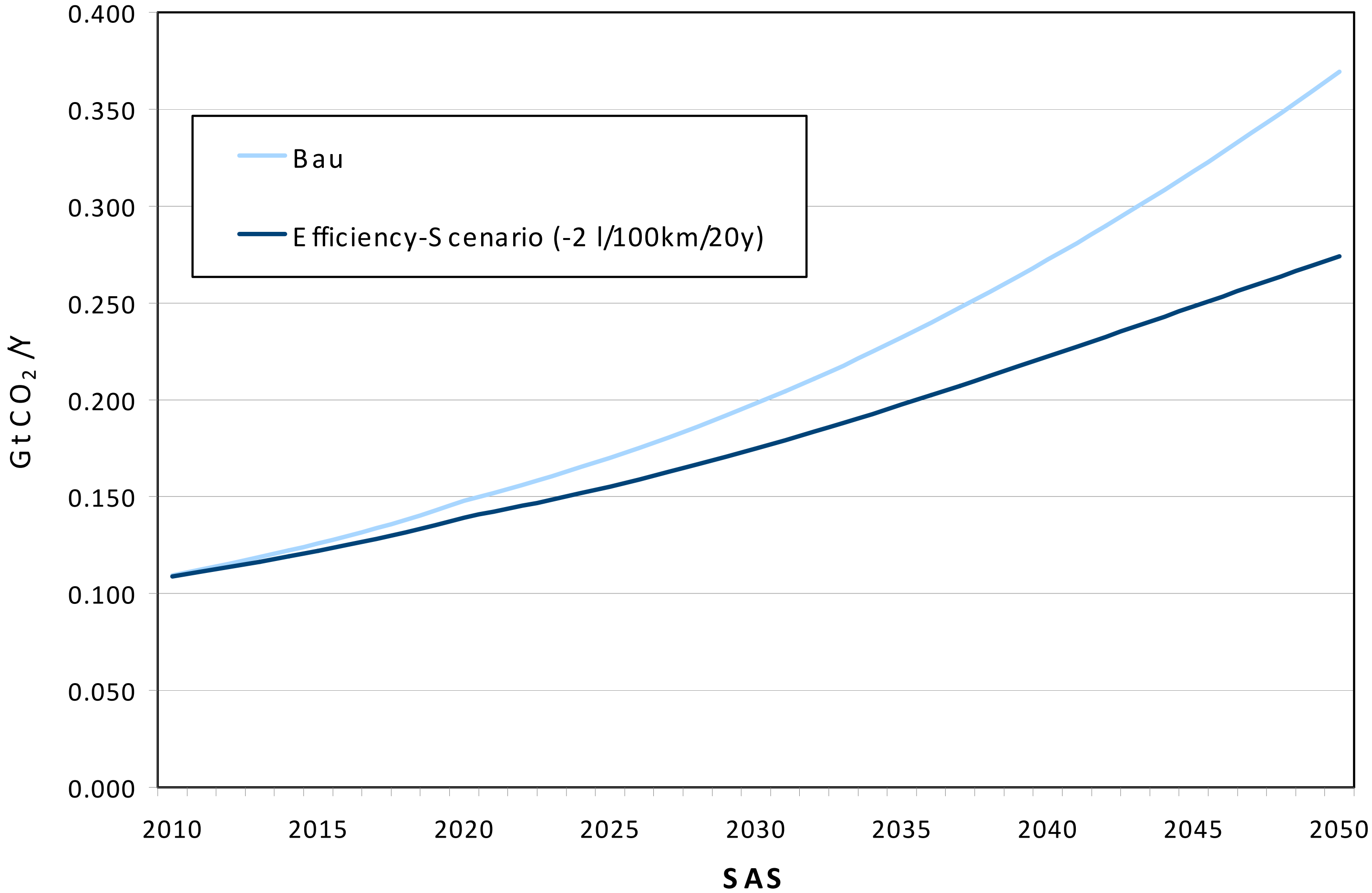
SG(+1)BSA



Source: own calculation

Relative reduction in emissions from mitigation scenario enhanced fuel efficiency in SAS

SG(+1)BSA



Source: own calculation

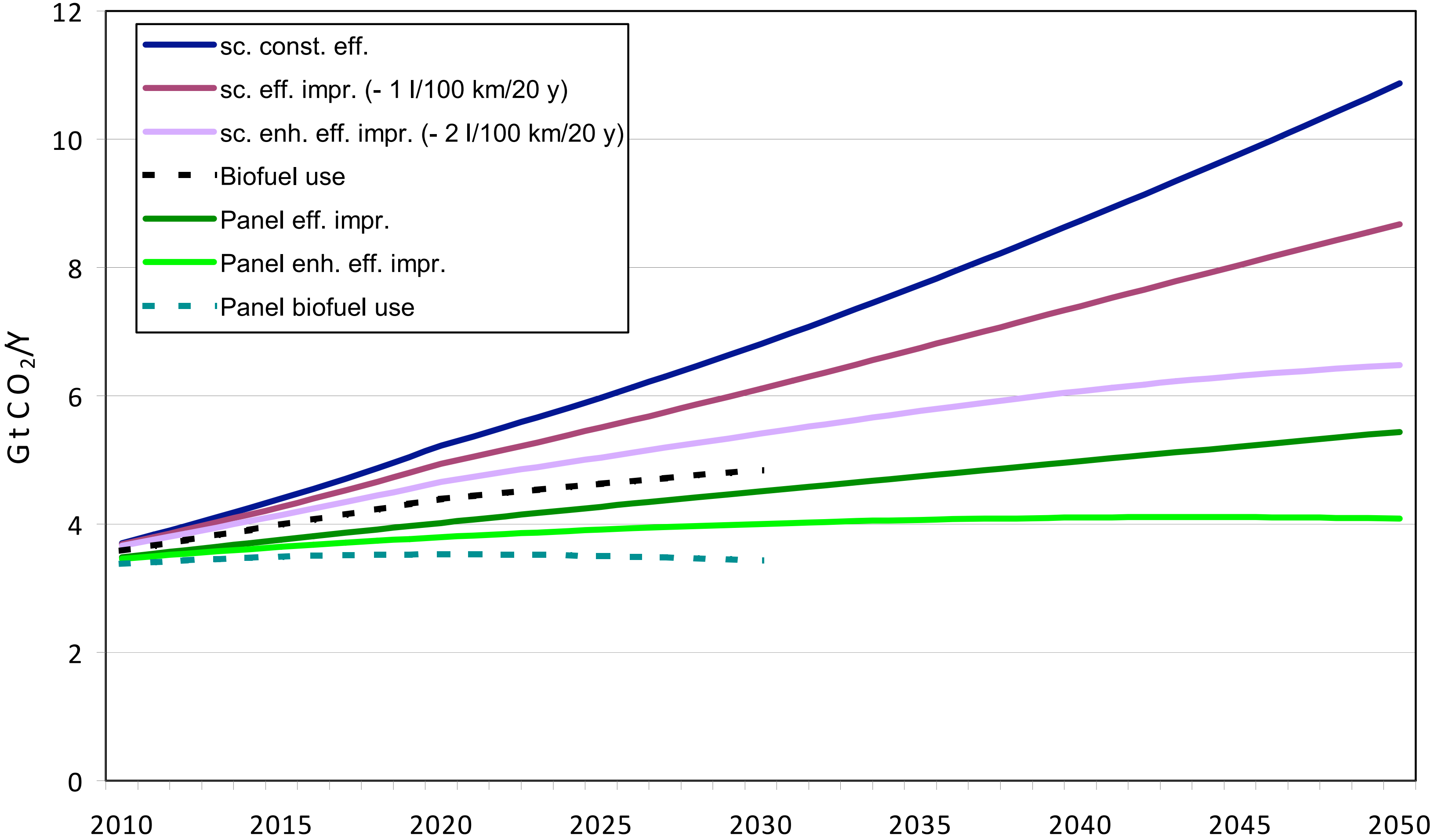
Mitigation scenario: biofuel blending
World biofuels production potential (DoE, 2008)

	2005	2010	2015	2020	2025	2030
USA	15.14	49.205	68.13	90.84	102.195	109.765
Brazil	18.925	22.71	34.065	45.42	56.775	60.56
West Europe	7.57	22.71	22.71	26.495	37.85	49.205
Rest of the World	3.785	7.57	18.925	41.635	68.13	94.625
Total	45.42	102.195	143.83	204.39	264.95	314.155

Baseline scenario for biofuel production, 2005-2030 (in billion litres ethanol equivalent). Source: DoE, 2008.

Modell assumption: average emission reduction over all biofuels changes linearly from -30% in 2005 to -80% in 2030 compared to the fossil energy equivalents due to technological improvements.

Mitigation scenarios: world biofuel use until 2030 (DoE, 2008)



Source: own calculation

Concepts for mitigation in passenger car transport

Demand-side/ Behavioral Approach

- consumer choice towards efficient/advanced technology cars
- shift in modal split
- reduce transport activities and needs
- change preferences regarding spatial patterns of housing, working and leisure to prevent urban sprawl

Supply-side/ Technological Approach

- enhance fuel economies
- develop/deploy techn. innovations of decarbonization
  - alternative fuels
  - alternative propulsion systems
  - optimize intermodality
  - improve quality of publ. transport

Thank you.

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