Decarbonising the Air Transport System ‘Challenges and Opportunities’

Tue 26th July 2022 (14:00 UTC)

A1 : Air Transport and Airport

WCTRS
World Conference on Transport Research Society

Little things.....

Q&A

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Agenda

- 14:00-14:10: Opening notes Professor Tae Oum
- 14:10-14:30: Presentation Ms Yue Huan, Dr Alejandro Block (IATA)
- 14:30-14:50: Presentation Professor Anming Zhang
- 14:50-15:00: Q & A
- 15:10-1540: Panel Discussion, Decarbonising the Air Transport System: Challenges and Opportunities
- 15:40-15:50: Q & A
- 15:50: Closing remarks Professor Martin Dresner

Opening Notes

- Professor Tae Oum
- President of WCTRS
- UBC Sauder School of Business

WCTRS
World Conference on
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1400-1410 (UTC)

The Industry’s Long Term Aspirational Goal (LTAG)

Ms Yue Huang and Dr Alejandro Block

WCTRS
World Conference on Transport Research Society

1410-1430 (UTC)

Aviation Commitment to Net Zero 2050

Environment & Sustainability

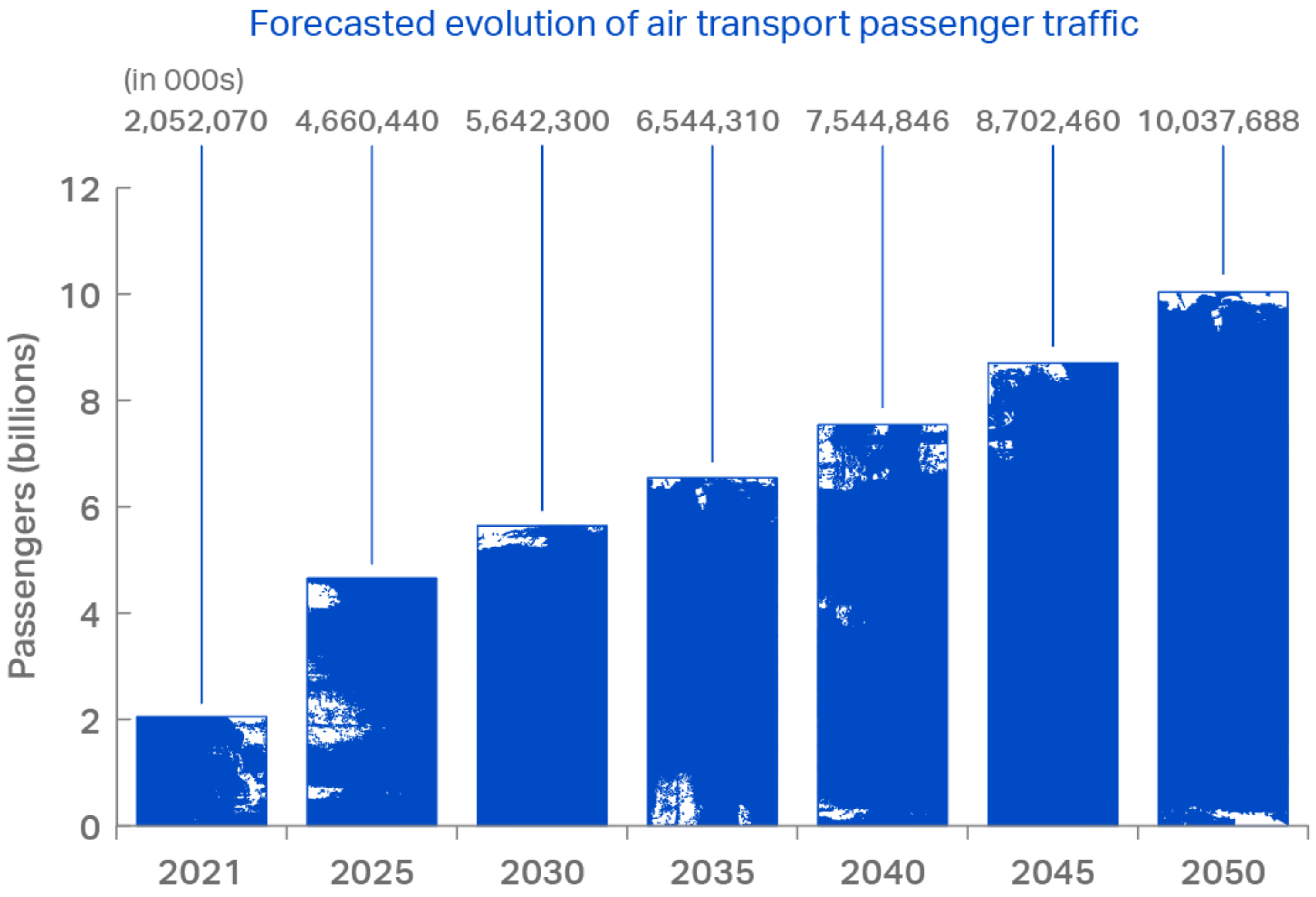
International Air Transport Association

Our commitment:

TO ACHIEVE NET ZERO CARBON EMISSIONS BY 2050

- Target aligned with Paris Agreement goal to keep global warming under 1.5 °C
- Aimed at keeping the benefit of global connectivity for future generations

Our challenge

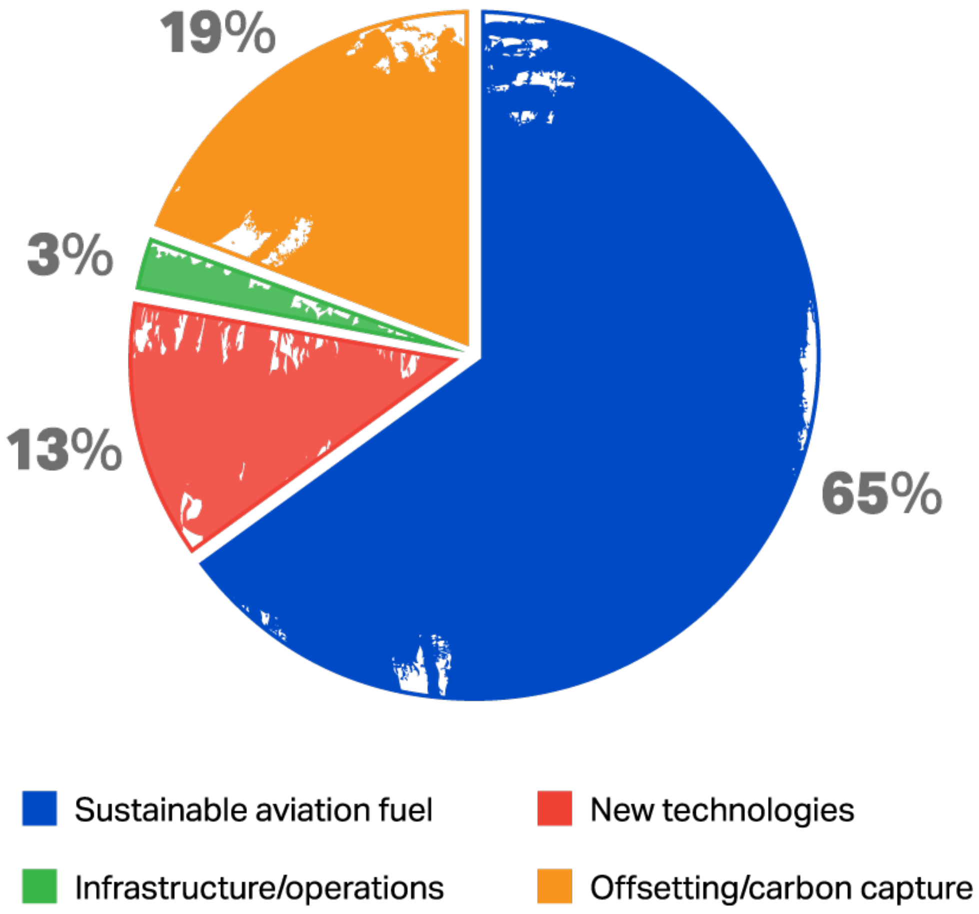


If Business-as-Usual in 2050

- over 10 billion passengers
- 1.8 Gigatons CO_2 to abate

The plan

Contribution to achieving Net Zero Carbon in 2050



Net Zero 2050 is achievable through:

Combination of measures

- Sustainable Aviation Fuel, new , technologies, operational and infrastructure improvements, and offsetting/carbon capture

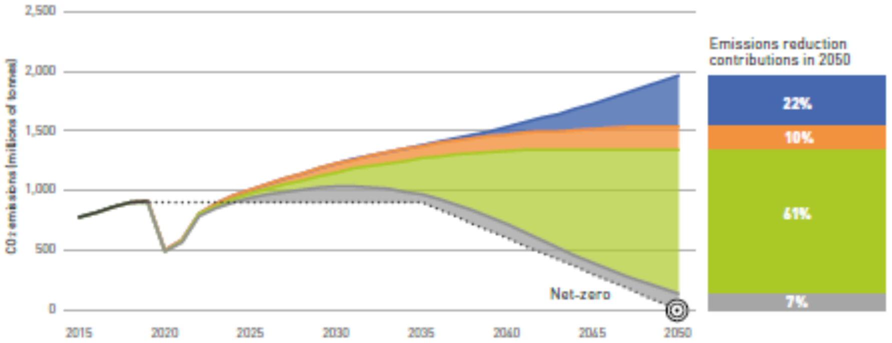
Collective effort

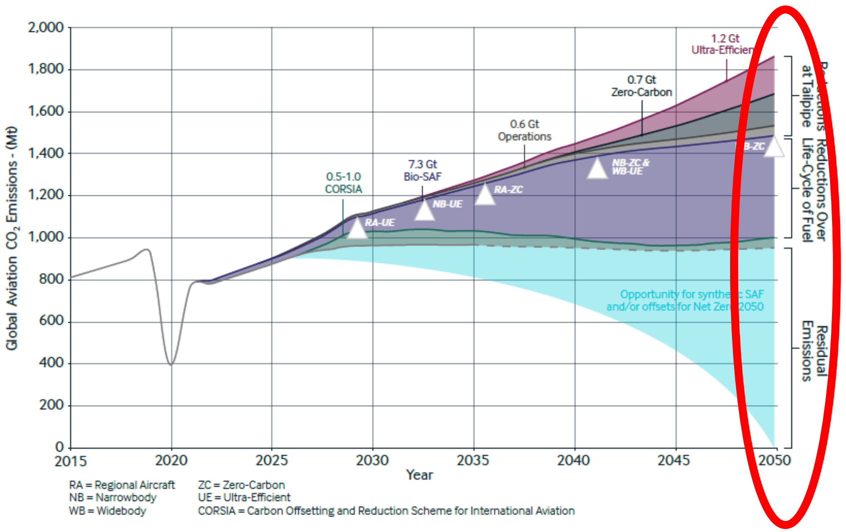
- of the entire industry together with governments, oil producers and investors

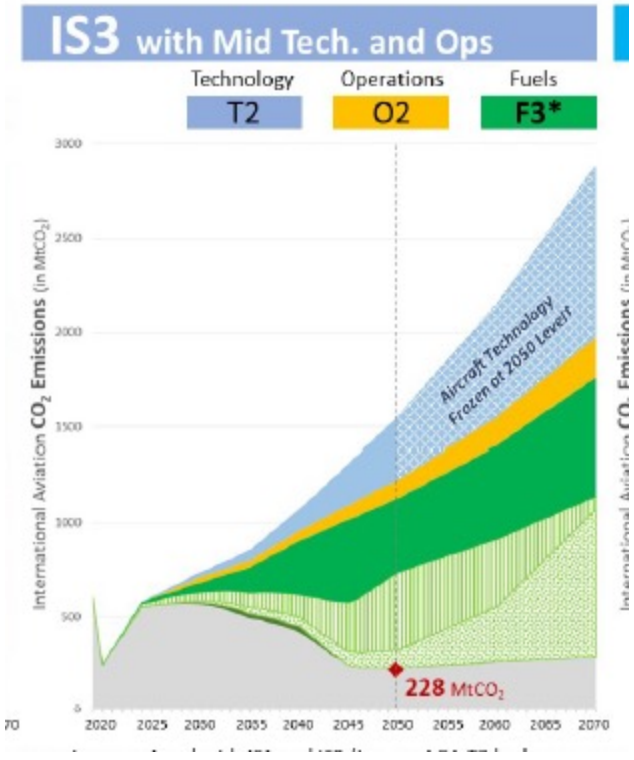
Indicative overview of where CO_2 measures could be deployed

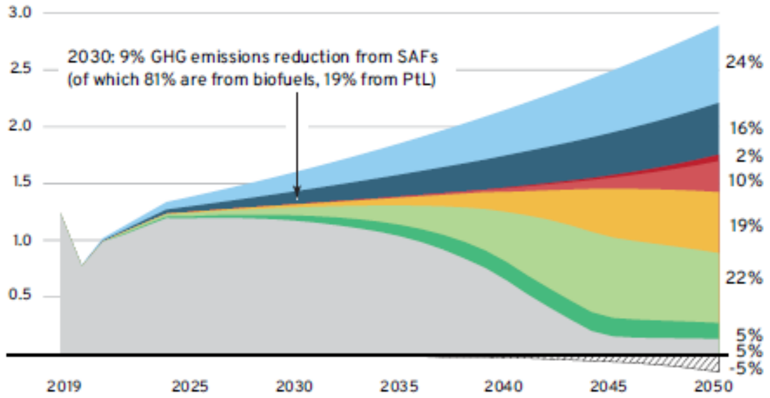
	2020	2025	2030	2035	2040	2045	2050	
Commuter » 9-50 seats » <60 minute flights » <1% of industry CO_2	**SAF**	**Electric** and/or **SAF**	**Electric** and/or **SAF**	**Electric** and/or **SAF**	**Electric** and/or **SAF**	**Electric** and/or **SAF**	**Electric** and/or **SAF**	~27% of CO_2 emissions
Regional » 50-100 seats » 30-90 minute flights » ~3% of industry CO_2	**SAF**	**SAF**	**Electric** or **hydrogen fuel cell** and/or **SAF**	**Electric** or **hydrogen fuel cell** and/or **SAF**	**Electric** or **hydrogen fuel cell** and/or **SAF**	**Electric** or **hydrogen fuel cell** and/or **SAF**	**Electric** or **hydrogen fuel cell** and/or **SAF**	
Short-haul » 100-150 seats » 45-120 minute flights » ~24% of industry CO_2	**SAF**	**SAF**	**SAF**	**SAF**	**Electric, hydrogen combustion** and/or **SAF**	**Electric, hydrogen combustion** and/or **SAF**	**Electric, hydrogen combustion** and/or **SAF**	
Medium-haul » 100-250 seats » 60-150 minute flights » ~43% of industry CO_2	**SAF**	**SAF**	**SAF**	**SAF**	**SAF**	**SAF**	**SAF** potentially some **Hydrogen**	~73% of CO_2
Long-haul » 250+ seats » 150 minute + flights » ~30% of industry CO_2	**SAF**	**SAF**	**SAF**	**SAF**	**SAF**	**SAF**	**SAF**	

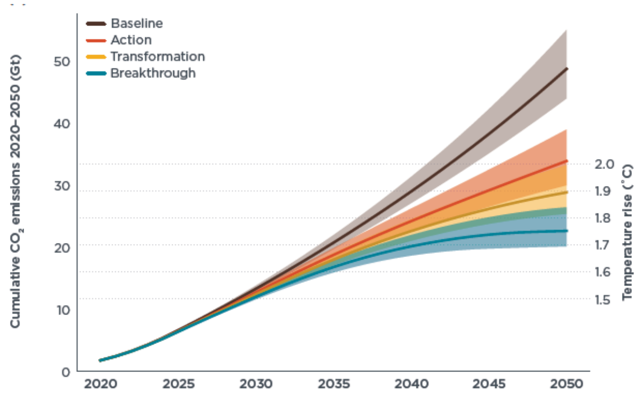
Decarbonization pathways





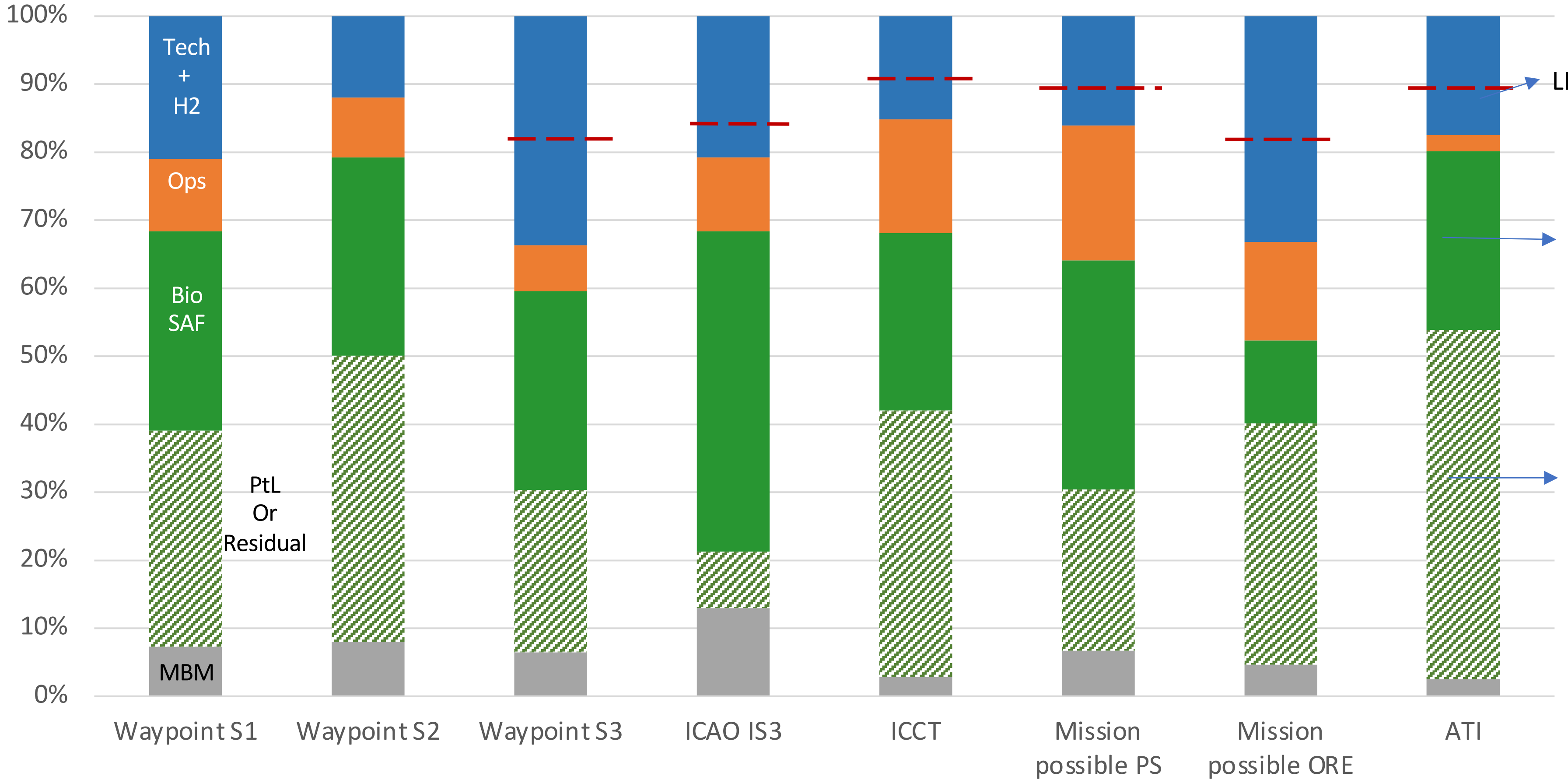






CO_2 reductions in 2050 - Energy Transition

In-flight energy use: ~6,500- 7,000 TWh (~ 2X 2019)

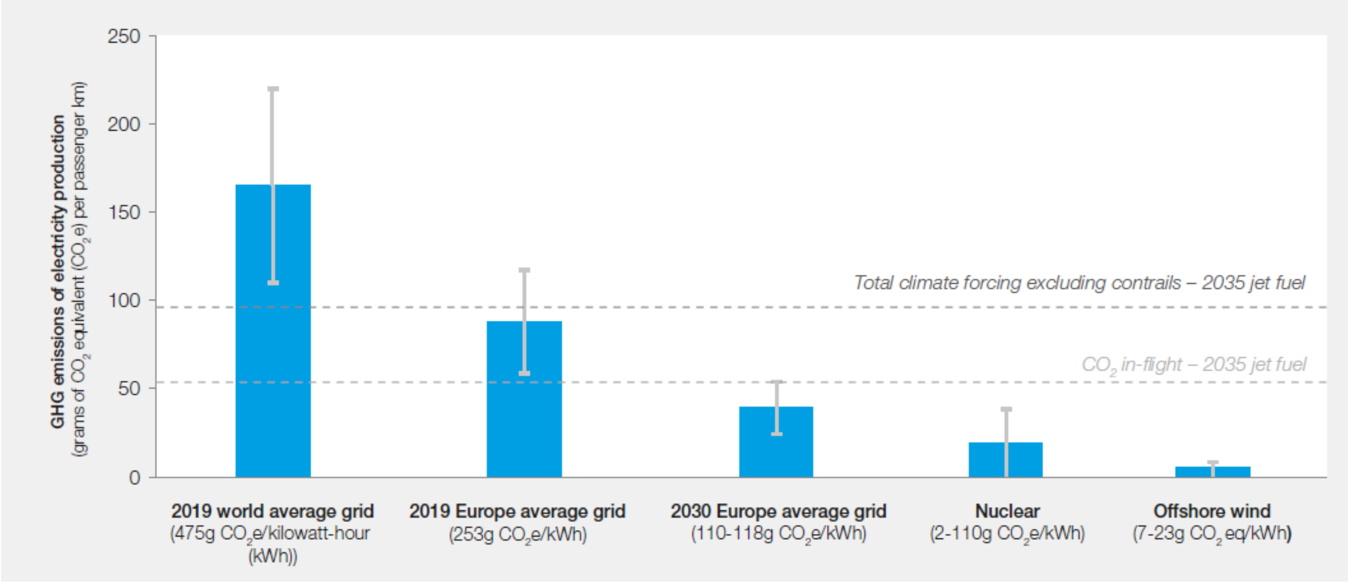


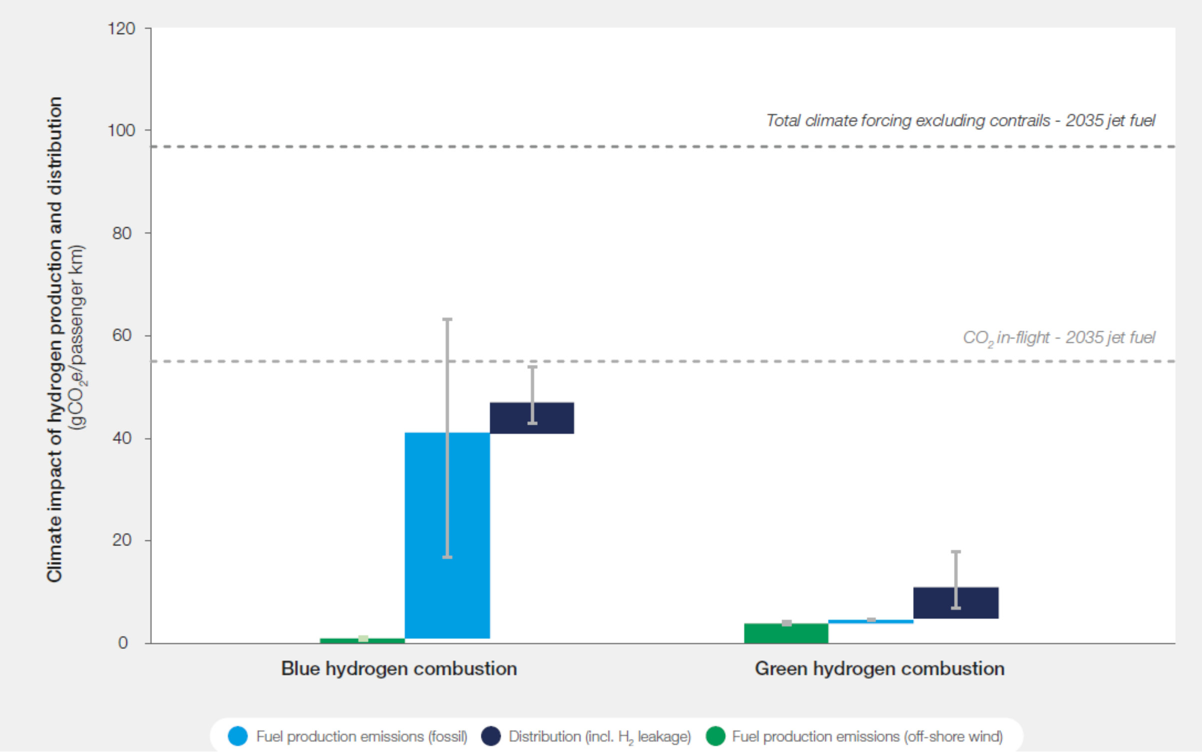
	Fuel mass (Mt)	H2 mass (Mt)	Energy (TWh)
LH_2	16	16	1,000
Bio SAF	190	13-100	450-1,800
PtL Kero	290	100*	10,400*
			~13,000

*If PtL

Order of magnitude results
V LARGE uncertainty!!

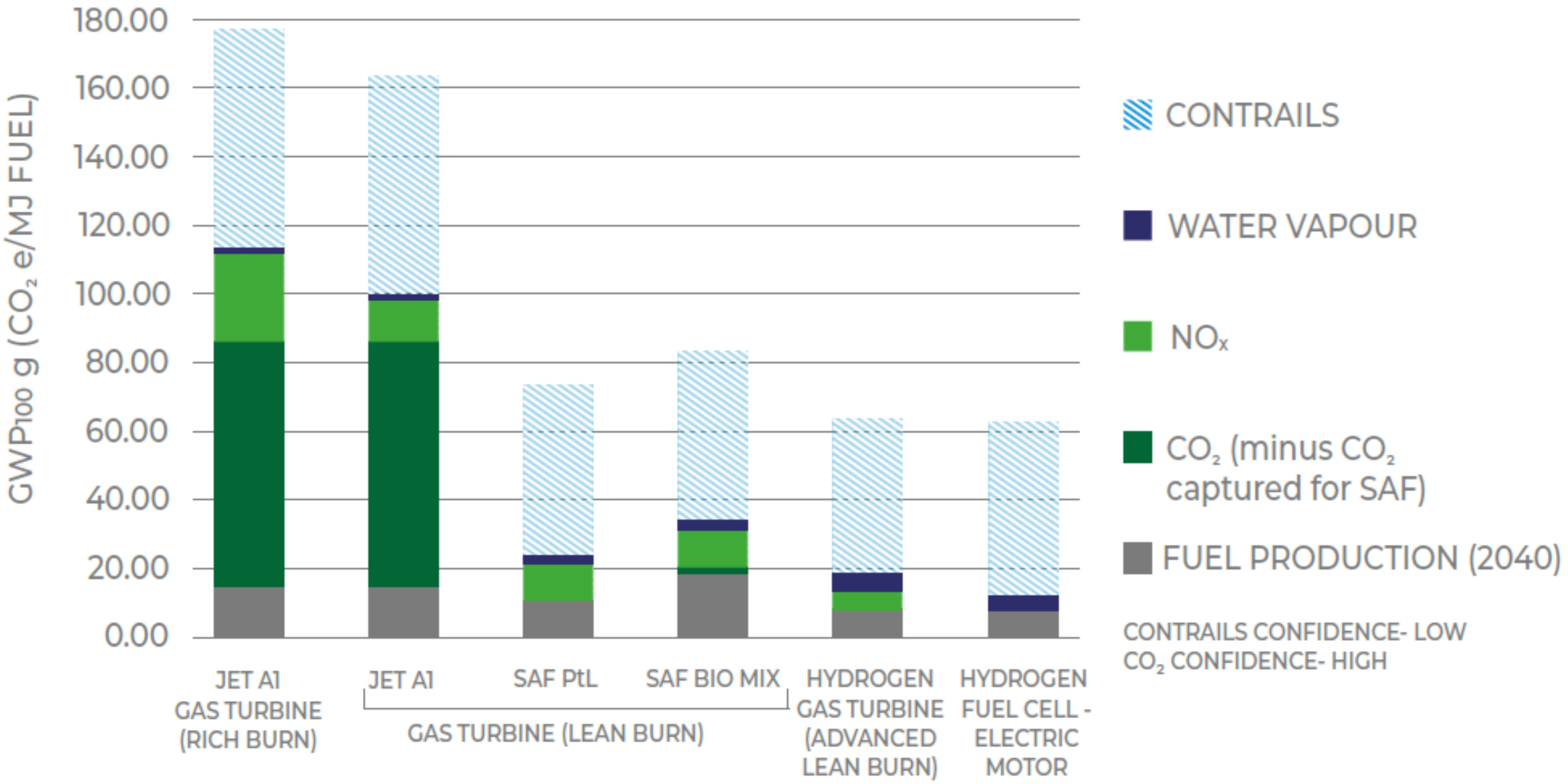
Life cycle emissions?





WEF, World Economic Forum and University of Cambridge Aviation Impact Accelerator, “Target True Zero: Unlocking sustainable battery and hydrogen-powered flight,” WEF, https://www.weforum.org/reports/target-true-zero-unlocking-sustainable-battery-and-hydrogen-powered-flight/, July 2022

Non- CO_2 effects?



S. Job, M. Campbell, B. Hall, Z. Hamadache and N. Kumar, "Sustainability Report - The life cycle impact of Hydrogen-Powered Aircraft," ATI, FlyZero, https://www.ati.org.uk/wp-content/uploads/2022/03/FZO-STY-REP-0005-FlyZero-Sustainability-Report.pdf, 2022

Assessing CO2 emissions of high-speed rail in China: Considering modal shifts and traffic generation effect

Professor Anming Zhang

UBC Sauder School of Business

WCTRS

World Conference on Transport Research Society

1430-1450 (UTC)

Q&A

Professor Anming Zhang
UBC Sauder School of Business

Ms Yue Huang
(IATA)

Dr Alejandro Block
(IATA)

1450-1500 (UTC)

Panel Discussion: Decarbonising the air transport, different challenges by region and countries

Prof. Anming Zhang

Prof. Tae Oum

Prof. Martin Dresner

Prof. Achim Czerny

Ms. Yue Huang

Dr Alejandro Block

1510-1540 (UTC)

Key Questions : To explore how to accelerate the decarbonisation to support aviation net zero

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- ✓ Market based mechanism
- ✓ Energy Transition : SAF, Electrification, Hydrogen
- ✓ Challenges and Opportunities : Different among the countries, regions, airlines, and airports

1510-1550 (UTC)

Closing remarks

Prof. Martin Dresner
Robert H. Smith
School of Business
University of Maryland

1550-1600 (UTC)

Assessing CO_2 emissions of high-speed rail in China: Considering modal shifts and traffic generation effect

Anming Zhang

Sauder School of Business, UBC

July 26, 2022 @ WCTRS_A1 (Air Transport and Airport) Seminar: <u>Decarbonizing the Air Transport System ‘Challenges and Opportunities’</u>

To meet Paris Agreement Goals, drastic transformation in airline industry is needed:

- Replace kerosene with biofuels in short term, and synthetic fuels in long term;
- Reduce demand for flights by, e.g.,

  i) raising ticket prices,

  ii) **partnering with high-speed rail (HSR), especially on short-/medium-haul routes**.

HSR: Multi-policy objectives

- Improve people's mobility through accessing inter-city transportation;
- Stimulate regional economic growth;
- Improve spatial distribution of traffic and economic developments across regions;
- **Reduce the negative environmental impact of transportation.**

Specifically, modal shift from other transport modes to HSR

- HSR is *generally* considered a cleaner substitute to air and highway transportation → "**Mode substitution**" **effect**

But, HSR may induce new travel demand → **"Traffic generation" effect**

Plus: HSR serves as a complement (e.g., feeder) for other modes, which in turn will increase these modes' demand → **"Mode complement" effect**

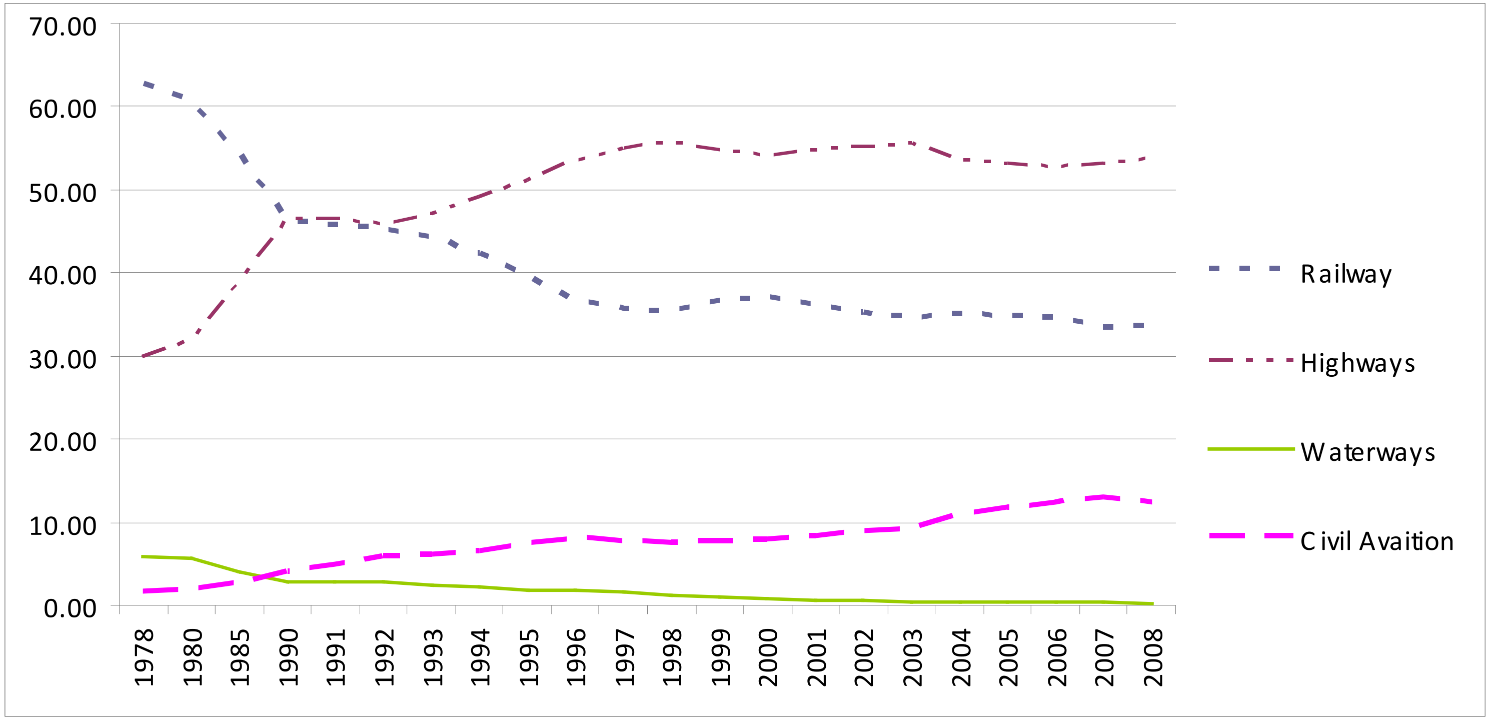
→ **Premature to conclude positive environmental impacts of HSR?**

Assessing Carbon Dioxide Emissions of high-speed rail: The Case of Beijing-Shanghai corridor *

Peihong Chen, Yuan Lu / Beijing Jiao Tong University
Yulai Wan / Hong Kong Polytechnic University
Anming Zhang / University of British Columbia

* Transportation Research Part D: Transport and Environment, 2021

Mode splits in China's inter-city passenger travel: RPK share 1978-2008



Source: China Statistical Year Book, 1979-2009

Operating statistics of China's HSR

Year	Operational length (km)	Share of overall rail length (%)	Pax carried (million)	Share of overall rail pax (%)	Pax-km (billion)	Share of overall rail pax-km (%)
2008	672	0.8	7.34	0.5	1.56	0.2
2009	2,699	3.2	46.51	3.1	16.22	2.1
2010	5,133	5.6	133.23	8.0	46.32	5.3
2011	6,601	7.1	285.52	15.8	105.84	11.0
2012	9,356	9.6	388.15	20.5	144.61	14.7
2013	11,028	10.7	529.62	25.1	214.11	20.2
2014	16,456	14.7	703.78	30.5	282.5	25.1
2015	19,838	16.4	961.39	37.9	386.34	32.3
2016	22,980	18.5	1221.28	43.4	464.10	36.9
2017	25,164	19.8	1752.16	56.8	587.56	43.7

Source: China Statistical Yearbook, 2018

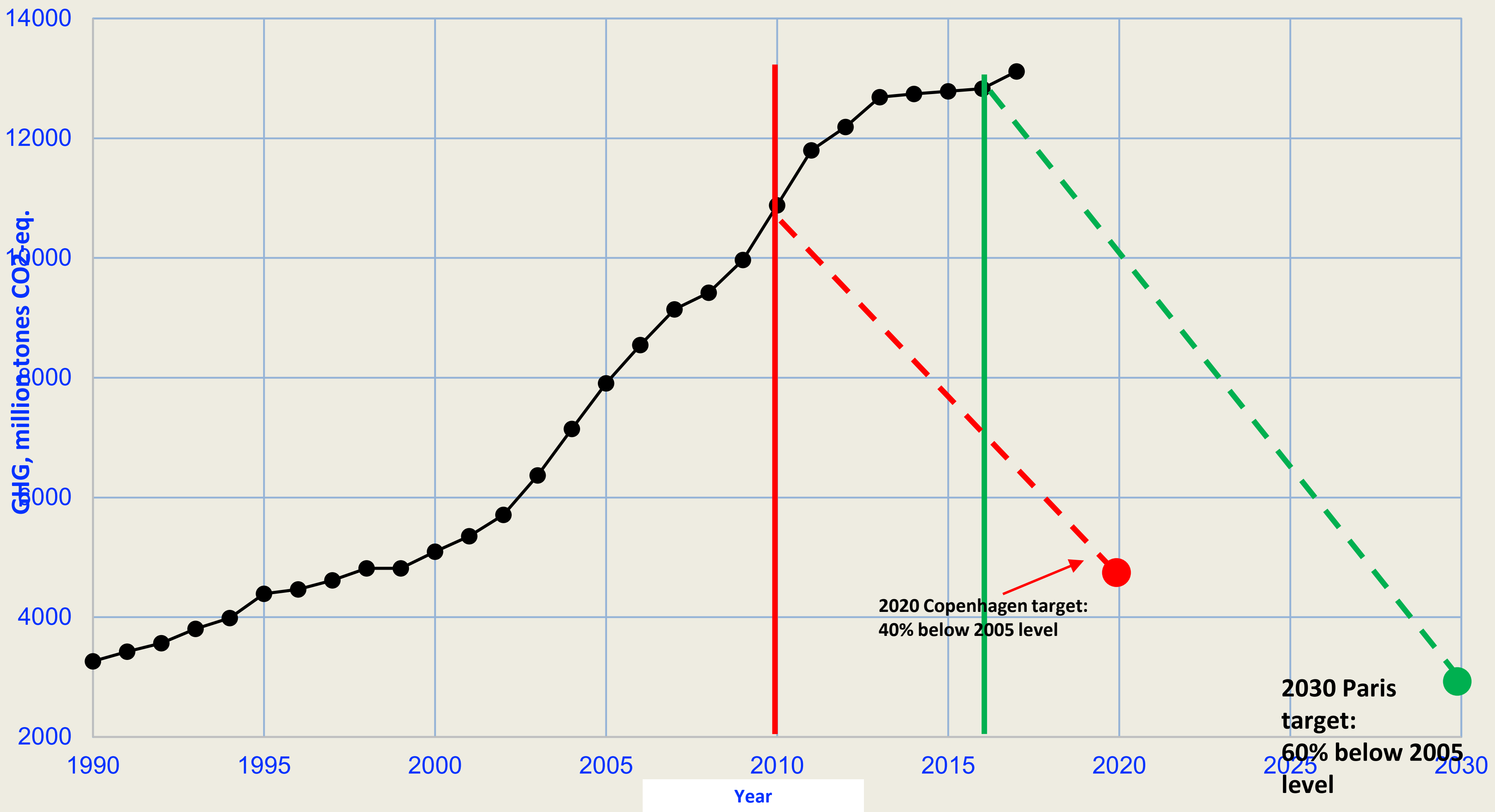
Climate policy

- China’s “**Carbon Peaking by 2030, and Carbon Neutrality by 2060**”: a key national policy (announced at UN, Sept 2020)

- **China’s 2020 & 2030 GHG targets**

No 2012 targets: As a developing county at the time when Kyoto Protocol was assigned, China had no obligations under that agreement

China's 2020 & 2030 GHG targets



Source: Climate Action Tracker

Highlights of the paper

- Conduct an **ex-post evaluation** of CO2 effects of the Beijing-Shanghai (**B-S**) HSR with **actual traffic** data

- B-S HSR line (1,318 km in total) serves **short-, medium- and long-haul** city-pair markets, and faces competition from:

  - Ordinary-speed railway (OSR)

  - Highway

  - Air transport

- Allow possibility that HSR may not be the cleanest among these alternative modes, even at operation stage

Highlights of the paper (cont.)

- Net CO2 emissions of B-S HSR are assessed
- The assessment framework incorporates both the **modal-substitution** and **traffic-generation** effects
- In addition to **operation stage**, avoided emissions from **infrastructure construction** and **vehicle manufacturing** are considered

  → **Life-cycle analysis (LCA)**

3. Evaluation Framework

3.1 B-S corridor

- In 1990s, an obvious mismatch between high transport demand and limited capacity in B-S corridor
- **Construction of B-S HSR began on April 18, 2008; the entire line started commercial service on June 30, 2011**
- Designed to accommodate 160 pairs of trains per day and move 160 million passengers per year in two directions
- Passengers and No. of train journeys increased rapidly from 2011 to 2017; both have exceeded designed levels since 2017

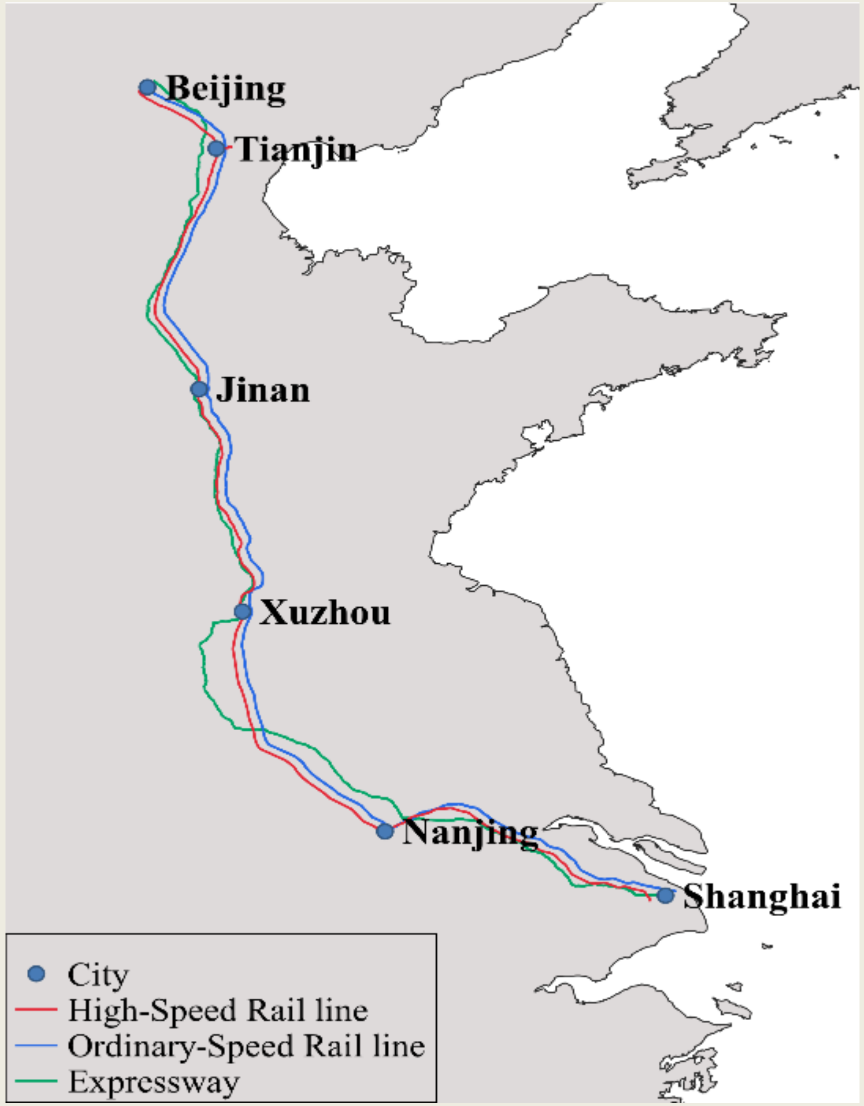


Figure 1: Beijing-Shanghai transport corridor

Table 1. B-S HSR traffic, 2011-2017

	2011	2012	2013	2014	2015	2016	2017
No. of train journeys operated	26493	64126	72240	94635	110062	137419	159201
Passengers (million)	24.5	65.1	83.9	105.9	122.4	151.8	179.0
Growth of passengers	---	34.5%	29.3%	26.2%	15.3%	23.7%	18.2%
Load factor	69.9%	67.7%	76.0%	76.5%	76.5%	76.1%	73.1%
Data source: Prospectus of Beijing-Shanghai HSR Co., Ltd							

3.1 B-S corridor (cont.)

- B-S HSR has become China's busiest line: its traffic density grew closer to that of Japan's Tokaido Shinkansen within just 6.5 years

- Inauguration of B-S HSR has different impacts on other transport modes along B-S corridor:
  - **OSR** passengers reduced in 2011 and 2012, and then gradually reached stability
  - **Expressways** traffic in B-S corridor grew slower
  - **Air routes** were heavily affected: Six routes have ceased; only three long-haul routes remained in 2017

3.2 Diverted and generated traffic

- Amount of HSR traffic diverted from transport **mode *i* (*i* = OSR, road, air)** is the difference between mode *i*'s actual traffic post-HSR and the projected traffic w/o HSR:

$$Q_i(t) = Q_{i0}(t) - Q_{i1}(t) \tag{1}$$

Q_i: Diverted traffic of mode *i*

Q_{i0}: Projected traffic of mode *i* as if B-S HSR were not in operation

Q_{i1}: Actual traffic of mode *i* with B-S HSR

$$Q_G(\mathrm{t}) = Q_h(\mathrm{t}) - \sum_i Q_i(t) \tag{2}$$

Q_G: Generated HSR traffic

Q_h: Actual traffic of B-S HSR line

3.2 Diverted and generated traffic

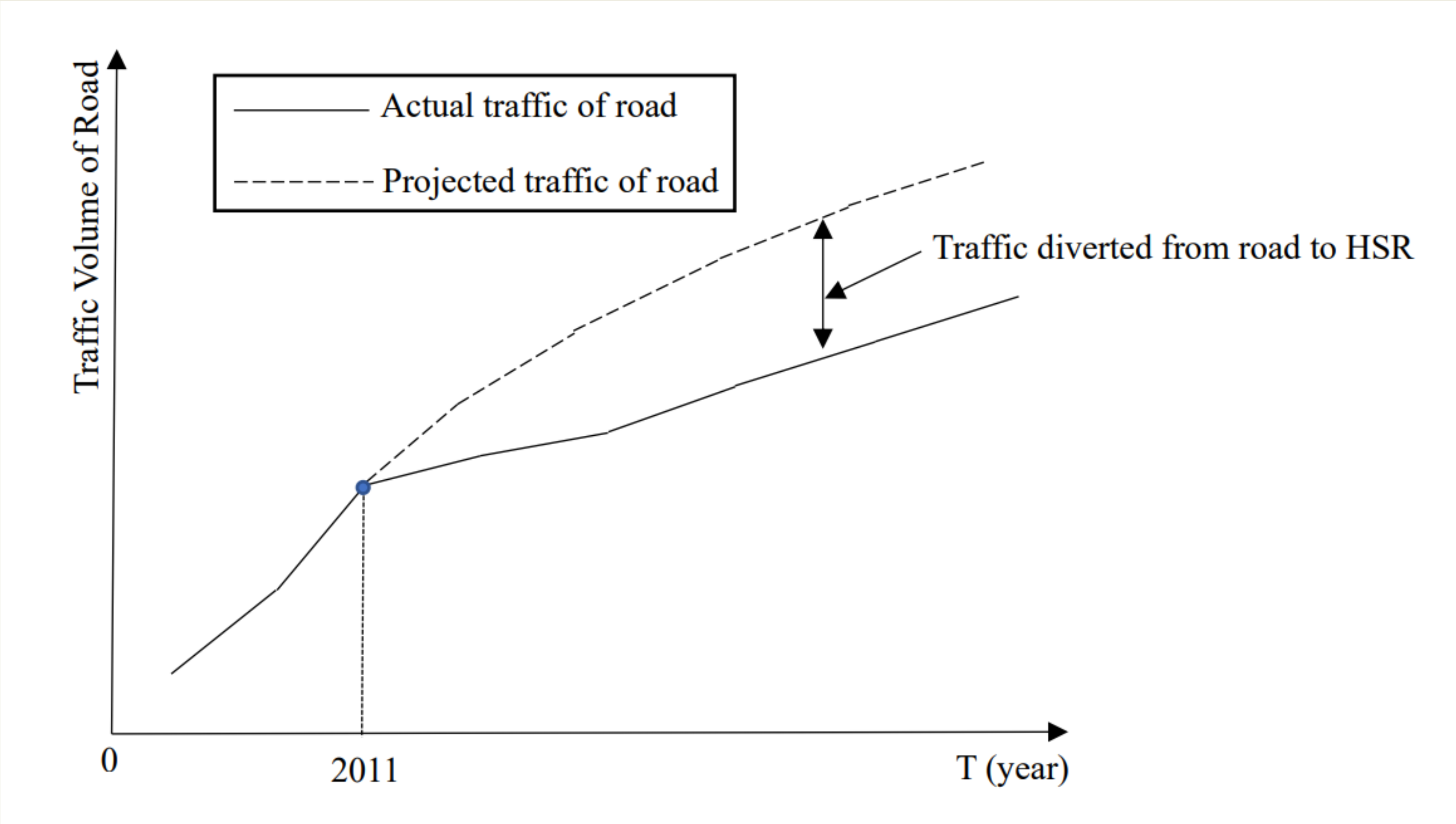


Figure 2: Diverted traffic from road to HSR

Table 6. Total diverted and generated traffic of B-S HSR, 2011-2017

		2011	2012	2013	2014	2015	2016	2017	Average
Passengers (million)	**Diverted from OSR**	58.84	74.66	70.64	67.70	71.82	75.71	76.63	77.00
	Diverted from road	30.05	46.43	47.61	66.48	63.67	86.55	121.70	68.93
	Diverted from air	1.97	5.06	6.64	7.84	8.88	9.75	10.77	7.27
	Generated	3.63	9.85	32.12	39.45	51.22	46.66	33.50	32.13
	Total	94.49	136.00	157.01	181.47	196.57	218.67	242.60	185.34
Proportion of HSR traffic (%)	**Diverted from OSR**	62.27	54.90	44.99	37.31	36.54	34.62	31.59	**41.55**
	Diverted from road	31.80	34.14	30.32	36.63	32.39	39.58	50.16	**37.19**
	Diverted from air	2.08	3.72	4.23	4.32	4.52	4.46	4.44	**3.92**
	Generated	3.84	7.24	20.46	21.74	26.56	21.34	13.81	**17.34**
	Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

3.2 Diverted and generated traffic (cont.)

- From 2011 to 2017, **diverted traffic** from:
  - OSR accounted for 41.55% of B-S HSR traffic
  - Road: 37.19%
  - Air: 3.92%

  vs. **generated traffic** of 17.34%.

- This is consistent with World Bank report (2019): for all corridors in China, 80%-90% of HSR traffic is diverted from other modes (OSR, road, air), and 10%-20% is newly generated.

3.3 Emissions assessment model

- **Net CO2 emissions (*NCE*)** of a new HSR project at year t:

$$NCE(t) = CE_1(t) - CE_0(t) \quad (3)$$

CE_1: CO2 from all transport modes when HSR exists

CE_0: CO2 from all transport modes when HSR does not exist.

$$NCE(t) = NCE_c(t) + NCE_m(t) + NCE_o(t) \quad (4)$$

- *NCE* decomposed to: Net emissions from infrastructure construction (NCE_c), vehicle manufacturing (NCE_m), and vehicle operation (NCE_o).

3.3 Emissions assessment model (cont.)

$$NCE_c(t) = CE_c^H(t) - \sum_i CE_c^i(t) \quad (5)$$

$CE_c^H(t)$: Actual CO2 emissions from construction of HSR infrastructure in year *t*

$CE_c^i(t)$: Avoided CO2 as fewer infrastructure-expansion projects needed for mode i due to traffic diversion to HSR.

$$NCE_m(t) = CE_m^H(t) - \sum_i CE_m^i(t) \quad (6)$$

$CE_m^H(t)$: Actual CO2 from manufacturing of HSR rolling stocks in *t*

$CE_m^i(t)$: Avoided CO2 from vehicle manufacturing for mode i due to traffic diversion.

3.3 Emissions assessment model (cont.)

$$NCE_o(t) = CE_o^H(t) - \sum_i CE_o^i(t) = E_h Q_h(t) - \sum_i E_i Q_i(t) \qquad (7)$$

$CE_o^H(t)$: Actual CO2 from operating HSR rolling stocks in *t*

$CE_o^i(t)$: Avoided CO2 from vehicle operation due to traffic diversion from mode *i*.

Let E_h be emissions rate of HSR, E_i emissions rate of mode *i*. Then, using eq. (2) we can convert (7) to:

$$NCE_o(t) = E_h Q_G(t) - \sum_i (E_i - E_h) Q_i(t) \qquad (8)$$

1st term on RHS of eq. (8): the extra emissions from operating HSR (i.e. generated traffic)

2nd term: the emission reduction (or increase) as some HSR traffic is diverted from other modes.

3.3 Emissions assessment model (cont.)

Lifetime net CO2 emissions, $LNCE$, can be written as:

$$LNCE = \sum_{t}^{lifetime} \{NCE_c(t) + NCE_m(t) + NCE_o(t)\} \quad (9)$$

Table 7. Lifespans of infrastructures and vehicles of transport modes

	Description	**Lifespan**
HSR & OSR		
Civil engineering work	Subgrades, bridges & viaducts, tunnels, station buildings	100 years
Track	Rails	30 years
Equipment	Telecom & signal equipment, energy provision equipment	50 years
Rolling stocks	High-speed train CRH380, train 25G	30 years
Expressway		
Civil engineering work	Subgrades, bridges & viaducts, tunnels, service station buildings	100 years
Pavement	Pavements	30 years
Passenger cars	Cars (Buick GL8)	10 years
Air		
Civil engineering work	Terminal building	100 years
Runway	Runway	30 years
Airplane	Airbus 320	20 years
Source: Baron et al. (2011)		

4. Net Emissions from Infrastructure Construction (NCE_c)

- Annualized net CO2 emissions from infrastructure construction is, from (5):

$$NCE_c(t) = CE_c^H(t) - \sum_i CE_c^i(t)$$

$$= \mathbf{184,541} - 5{,}794\ (\text{OSR}) - 18{,}499\ (\text{Road}) - 884\ (\text{Air})$$

$$= 159{,}364\ (\text{t CO2 per year})$$

- **Since freight traffic of B-S OSR has not increased much (to the contrary of expectation) – its capacity has not been fully utilized – the avoided expansion due to HSR is not large.** The avoided highway expansion can offset a large share of emissions from HSR construction, while the expansion of aviation infrastructure is negligible.

- As a result, the net CO2 emissions from B-S HSR construction are still huge, due to small amount of avoided expansion of the other transport modes.

Table 8. Carbon footprint of infrastructure construction of B-S HSR

Components	Emissions factors [a]	Quantity [b]	CO_2 emissions (t CO_2 per year)	Share of CO_2 emissions
Railway equipment	3.5 t CO_2 per km and year	1318 km	4613	2.5%
Rails	31.6 t CO_2 per km and year	1318 km	41649	22.6%
Subgrade	22 t CO_2 per km and year	241 km	5302	2.9%
Tunnels	171 t CO_2 per km and year	16 km	2736	1.5%
Viaducts	115 t CO_2 per km and year	956 km	109940	59.6%
Bridges	183 t CO_2 per km and year	105 km	19215	10.4%
Main Stations	82 t CO_2 per station and year	6 stations	492	0.3%
Secondary Stations	33 t CO_2 per station and year	18 stations	594	0.3%
Total	140 t CO_2 per km and year	1318 km	**184,541**	100.0%

Sources: [a] Baron et al. (2011), [b] Prospectus of Beijing-Shanghai HSR Co., Ltd

5. Net Emissions from Vehicle Manufacturing (NCE_m)

- The annualized net CO2 emissions from vehicle manufacturing can be calculated:

$$NCE_m(t) = CE_m^h(t) - \sum_i CE_m^i(t)$$

$$= 58{,}067 - 6{,}887 - 47{,}416 - 520$$

$$= 3{,}254 \text{ (t CO2 per year)}$$

- Majority of the emissions from manufacturing of HSR rolling stocks is offset by the avoided emissions as fewer passenger vehicles are produced due to traffic diversion from B-S expressway, leading to a small NCE_m.

6. Net Emissions from Vehicle Operation (NCE_o)

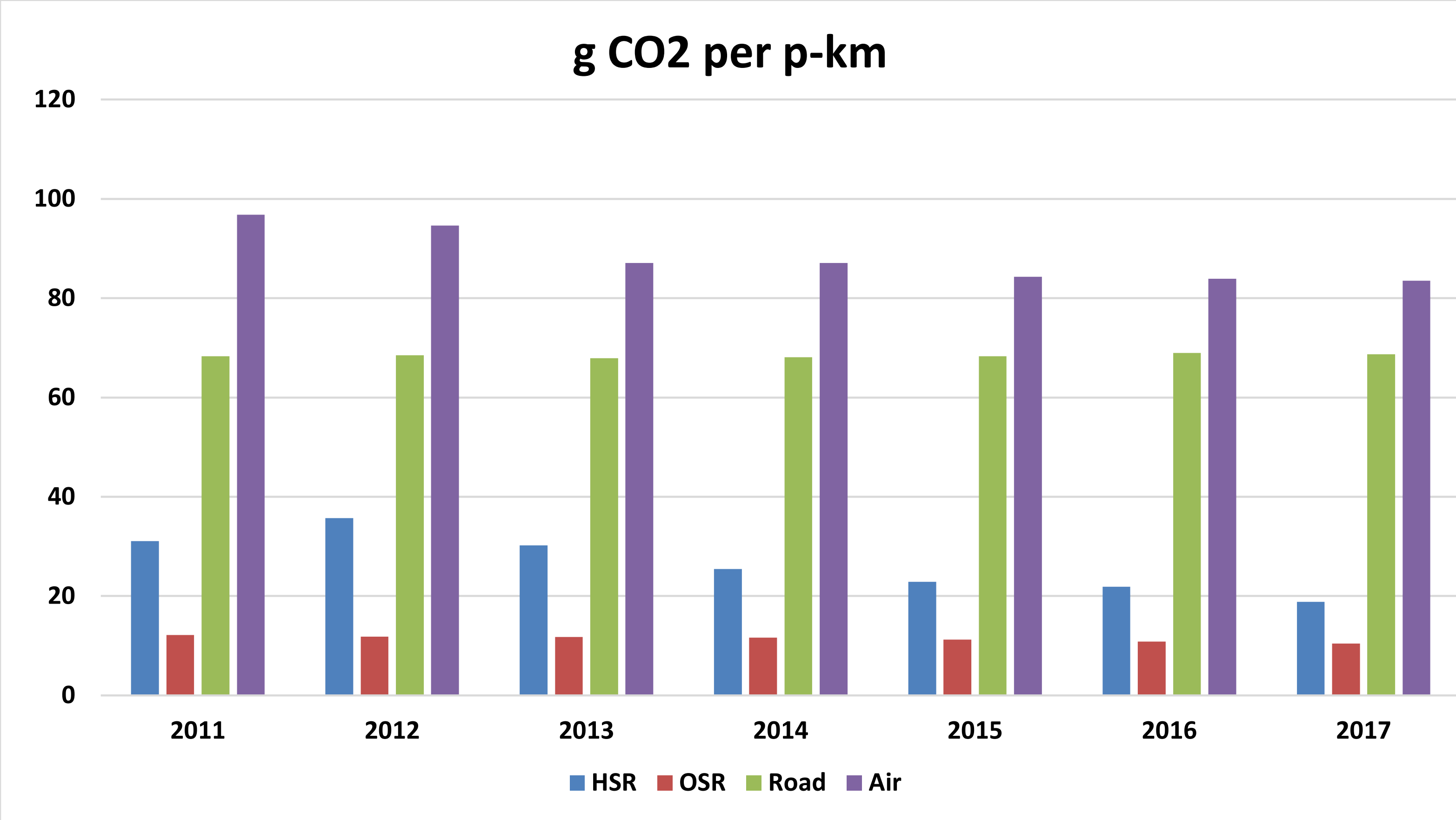


Figure 3: CO2 emissions per unit passenger traffic of 4 modes in B-S corridor

- Air transport has the highest CO2 emissions rate during vehicle operation, followed by road, HSR, and OSR
- In 2017, **Air's emissions rate is 4.4 times of HSR's; Road: 3.6 times of HSR; HSR: 1.8 times of OSR**

6. Net Emissions from Vehicle Operation (NCE_o) (cont.)

- HSR trains use electric power (about zero CO2 during operation). However, electric energy for railway operation in China mainly comes from thermal-power generation, and a large amount of CO2 is produced in the process of coal-fired power generation

- The carbon intensity in China for operating HSR is much higher than that in, for example, the UK and Canada

- But this intensity has been falling (Fig. 3), reflecting:
  i) decreasing share of thermal-power generation in China
  ii) its technology advancement

Table 17. CO2 emissions rate of B-S HSR

	2011	2012	2013	2014	2015	2016	2017
National share of thermal power over total power [a]	82%	79%	78%	76%	74%	73%	72%
Emission coefficient (C_e) (t CO_2 per MWH) [a]	0.748	0.725	0.722	0.714	0.690	0.664	0.641
CO2 emissions rate (E_h) (t CO2 per million p-km)	31.10	35.68	30.24	25.42	22.88	21.85	18.85
Note: MWH = million watt-hour Source: [a] 2011-2017 Baseline Emissions Factors for Regional Power Grids in China.							

Table 23: Net emissions from vehicle operation (NCE_o), 2011-2017

Year	Emissions from diverted traffic (t CO2)	Emissions from generated traffic (t CO2)	Total (t CO2)
2011	68272.49	113496.34	181768.83
2012	261762.07	253536.01	515298.08
2013	41397.88	376330.75	417728.63
2014	-336164.52	519281.03	183116.51
2015	-376031.03	425507.60	49476.57
2016	-558188.87	422263.70	-135925.16
2017	-771169.50	483243.50	-287926.00

- CO2 emissions from diverted traffic have been increasing for the first three years: **At the initial stage, diverted traffic to HSR mainly comes from OSR**, while diverted traffic from road and air increases later than OSR. The **emissions rate of HSR is greatly reduced as its ridership rises**, but that of other surface modes has almost no change: Highway has little scale economy and OSR has little change in traffic: together causing the emissions of diverted traffic to become negative in 2014, and then with an increasing magnitude over time
- **Net CO2 emissions from operation has become negative since 2016**, indicating that although more travel demand is accommodated with HSR, **the CO2 emissions from vehicle operation in B-S corridor are still lower than the non-HSR case**.

7. Lifetime Net Emissions (*LNCE*)

Table 24: Lifetime net CO2 emissions of the B-S HSR project

Lifetime (year)	Net emissions from infrastructure construction (t CO2)	Net emissions from vehicle manufacturing (t CO2)	Net emissions from vehicle operation (t CO2)
0	15936445		
1 (2011)		3254	181769
2 (2012)		3254	515298
3 (2013)		3254	417729
4 (2014)		3254	183117
5 (2015)		3254	49477
6 (2016)		3254	-135925
7 (2017)		3254	-287926
8 (2018)		3254	-457447
9 (2019)		3254	-623468
10 (2020)		3254	-789489
11 (2021)		3254	-955510
12 (2022)		3254	-955510
⋮		⋮	⋮
100 (2110)		3254	-955510

Findings on LNCE:

- Based on Table 24: LNCE of B-S HSR becomes negative after 26th year of operation:

  - Increased CO2 emissions from infrastructure construction and vehicle manufacturing completely offset by the emissions reduction from vehicle operation within 26 years

- **This is due largely to:**

  1) High HSR traffic density

  2) Sufficient traffic diversion from road and air

8. Conclusion

Table 25: CO2 emissions per unit of traffic in B-S corridor

	HSR	OSR	Expressway	Air
CO2 emissions from construction (g CO2/p-km-year)	2.21	0.58	1.84	0.05
CO2 emissions from vehicle manufacturing (g CO2/p-km-year)	0.29	0.90	3.90	0.48
CO2 emissions from vehicle operation (g CO2/p-km-year)	18.85	10.45	68.73	83.48

a) CO2 emissions from infrastructure construction:

- HSR has higher CO2 emissions from infrastructure construction than OSR, expressway, and air
- Although a large share of HSR traffic is diverted from the other modes, the avoided infrastructure expansion of those modes has little effect in offsetting its infrastructure construction emissions
- Generally, emissions from construction of a new HSR line are large

8. Conclusion (cont.)

b) CO_2 emissions from vehicle manufacturing:

- HSR has much lower emissions from vehicle manufacturing than from construction or vehicle operation
- On per traffic unit, HSR also has lower emissions from vehicle manufacturing than other transport modes, esp. highway
- Since a considerable amount of traffic is diverted from highway, CO_2 emissions from manufacturing can be largely offset
- Thus, annual emissions from manufacturing is small

8. Conclusion (cont.)

c) **CO2 emissions from vehicle operation:**

- The emissions reduction effect of an HSR project mainly comes from vehicle operation
- The emissions rate of B-S HSR has continuously fallen as the traffic density of HSR increases over time
- Overall, OSR has the lowest emissions rate, followed by HSR, road, and then air
- Since most of the diverted traffic came from OSR in earlier years, CO2 emissions of the diverted traffic were *increased* in the first three years
- As road and air increased their share of diverted traffic to about 40% each, CO2 emissions of the diverted traffic eventually turned to negative in **2014**

As a result, net CO2 emissions (after taking account of generated traffic) from vehicle operation turned to negative in **2016**

8. Conclusion (cont.)

d) CO2 emissions throughout lifespan of B-S HSR:

- Newly generated CO2 emissions due to HSR infrastructure construction and vehicle manufacturing can be completely offset by the CO2 reduction from vehicle operation after **26 years** of HSR operation
- While B-S HSR has improved average travel speed and accommodated new travel demand in B-S corridor, lifetime net CO2 emissions will be lower than the scenario without the project
- **For other HSR projects with lower traffic volume, the emissions payback period is expected to be longer**

Future Research

– Chen et al. (2021) has examined (and quantified) both the mode-substitution and traffic-generation effects over the mode lifetime

– The Beijing-Shanghai corridor

- **Title of this presentation: "Assessing CO2 Emissions of High-Speed Rail in China"**

1) Extend to other routes in China (to have a comprehensive assessment: % reduction in total CO2)

2) Incorporate **mode-complement effect**: HSR as complement (e.g., feeder) to other modes, stimulating traffic of those modes

The **mode-complement effect** is discussed in:

- Zhang, A., Wan, Y., & Yang, H. (2019), "Impacts of high-speed rail on airlines, airports and regional economies: A survey of recent research," Transport Policy, 81.

- Conduct theoretical analysis on the three effects (substitution, complement, and traffic-generation) in a single model.

Relatedly, impact of HSR on industry development and special structure: e.g. “core periphery” analysis,

- Zhou, Z., & Zhang, A. (2021), “High-speed rail and industrial developments: Evidence from house prices and city-level GDP in China,” Transportation Research Part A: Policy and Practice

- The “spillover effect” (Shanghai-Suzhou) vs. the “siphon effect” (Beijing-Tianjin) have different impacts on the three effects (substitution, complement, and traffic-generation)

- **Such analyses not only endogenize labor mobility, but also help assess, *ex-ante*, HSR projects**

A comprehensive literature review:

- Jiang, C., Wan, Y., Yang, H., & Zhang, A. (2021), “Impacts of high-speed rail projects on CO_2 emissions due to modal interactions: A review,” Transportation Research Part D Transport and Environment

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Thank You!

‘Net Zero’ in Air Transport:
Thank you to the WCTRS SIG-A1 leaders (Air Transport Research Group) for this important Summer 2022 Conference

Prof. Tae Hoon Oum

Sauder School of Business, University of British Columbia
and
President, the WCTR Society

A mural in Bucharest !

New issues – Net Zero campaign need to address

1. Challenges for Achieving Net Zero target in Air Transport

- Biofuel development is lagging far behind EV battery program (less investment)
- Thus, achieving Aviation Net Zero target requires more clarity in how to implement Global MBM (Market Based Measures) – what's possible and what's NOT possible; how do we prevent cheating ?

2. Effects of mutual cancellation of the 'overfly rights' (First Freedom right) because of Putin's invasion of Ukraine ➔ very significant increases of flight distances ➔ negative effects on Net Zero campaign

3. Anti-Globalization and Coldwar II are likely to reshape Global Supply Chain: Air Cargo transport network may need to change?

- ❑ Petersen Inst. Of International Economics (PIIE) calls it **'Accelerated Corrosion of Globalization'**

- ❑ **This may have major impacts on the way we need to organize int'l logistics and transport system**
  - **Just-in-Time (JIT)** Supply Chain and transport – **thrown out the window**
  - **Strategic reserve inventories** (e.g., semi-conductor) **became important**
  - **Coldwar II and balcanization of the world economic system** may change spatial distribution of transport demands ➔➔ **reshaping transport network and intermodal transport network**
  - Less efficient but necessary adjustments in int'l transport network (freight, passengers) may need to occur ➔➔ **reshaping of the spatial demand for transport** need to be researched

➔ Recalibration of the Net Zero program may be necessary

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Tae Oum, the WCTRS President

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  Symposia.cirrelt.ca/WCTRS2022-virtual/en

- WCTRS Triennial World Conference: 17-21 July, 2023 (Montreal)
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Thank you !!!
Merci !!!
Danke !!!
Obrigado !!!
Gracias !!!

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