# 2019 Seoul Fuel Ethanol Conference
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# Life Cycle Modeling and Tailpipe Emissions Modeling

## Tailpipe Emissions:

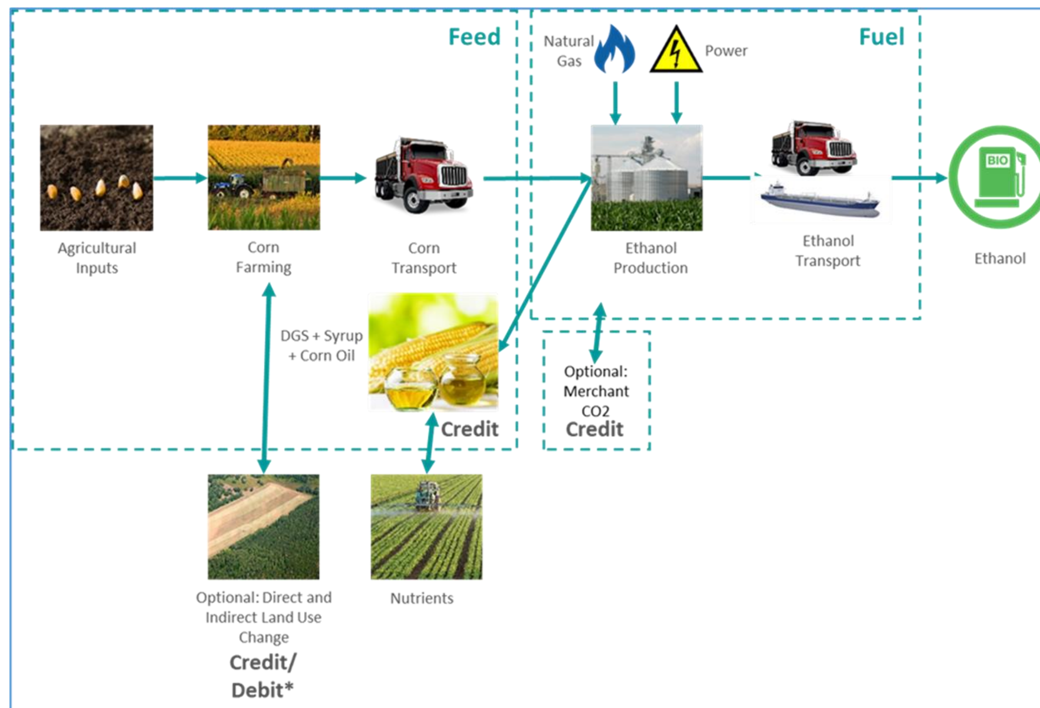
Assess **Local Air Emissions Impact** from Vehicle Traffic for key pollutants and air toxins:

- Particulate Matter,
- Carbon Monoxide,
- Nitrogen Oxides,
- Volatile Organics
- Air Toxins (Benzene; 1,3 Butadiene, Aldehydes)

## Life Cycle Emissions:

Assess **Emissions Impact from Cradle to Grave (e.g. Well to Wheel WTW)**

- Useful for all emissions but particularly for emissions with global impact such as Greenhouse Gas Emissions (GHGs)

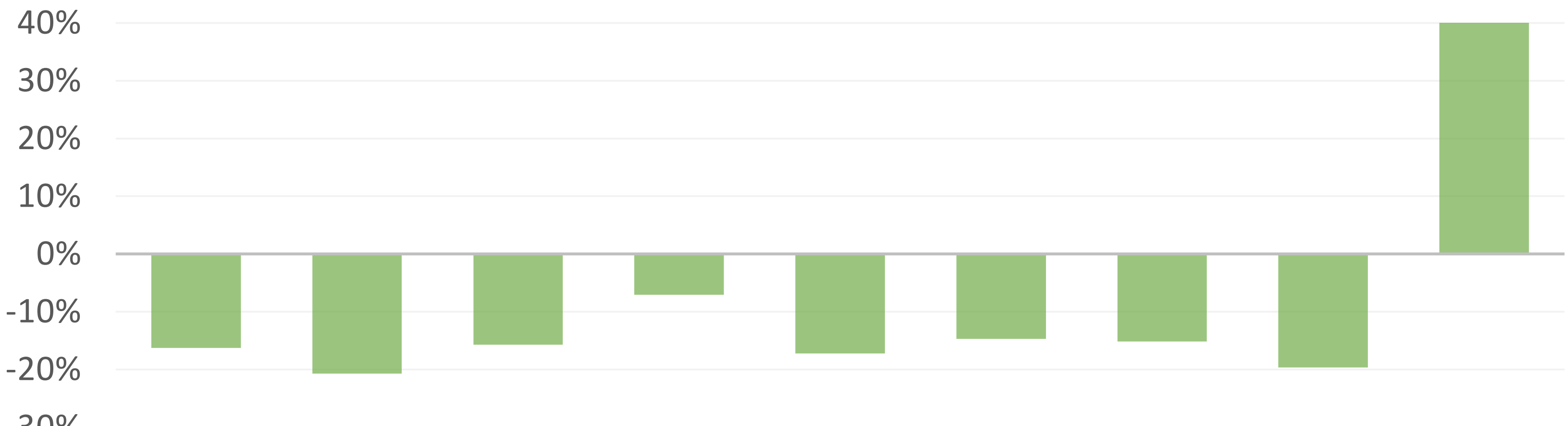


# Worldwide Literature Summary on Vehicle Emissions with 10 percent ethanol blended gasoline (E10)

| Study Name | Vehicles | Test cycle | Location | E 10 (% change wrt E0) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | THC | NMHC | CO | NOX | PM | Benzene | 1,3-butadiene | Formaldehyde | Acetaldehyde |
| Karavalakis et al., 2012 | 1984-2007 Gasoline vehicles (Total 6), One additional 2007 Flex Fuel Vehicle | FTP-75 | California | -12.80% | | | 13.60% | | -29% | -30% | -44% | 16% |
| Bertoa et al., 2015 | One Euro 5a flex-fuel light duty vehicle (FFV) equipped with a three way catalyst (TWC) and a turbo charged air intake system | WLTC | Italy | -65% | -68% | 13% | -24% | | -56% | | -50% | 133% |
| SAE, 1992 | Ford Valencia SI engine | | United States | -4.90% | -5.90% | -13.40% | 5.10% | | -11.50% | -5.80% | 19.30% | 159.00% |
| NREL, 2009 | 1999-2007 Gasoline vehicles (Total 16) | LA 92 | United States | | -12% | -15% | -5.50% | | | | -85% | 9% |
| Storey et al., 2010 | 2007 Pontiac Solstice | FTP-75, US06 | United States | | -20% | 3% | -42% | -6% | | | -29% | 95% |
| ORNL 2012 | 19 Tier 2 and 8 Tier 1/NLEV | FTP-75 | United States | | -7.02% | -2.36% | 34.26% | | | | -96% | 17% |
| Ozsezen et al. 2011 | Test Vehicle - 1.4i SI engine, Water-cooled, four stroke, multi point injection | wide-open throttle conditions and at the vehicle speeds of 40, 60, 80 and 100 kmph | Turkey | -14% | | -2.60% | -1.30% | | | | | |
| Schifter et al., 2011 | 4 vehicles older than 1992, 17 vehicles between 1993 - 1997 and 9 vehicles 2000-2004 | FTP-75 | Mexico | -5% | | -13.70% | -2.70% | | -10% | 7% | 0% | 19% |
| Zhu et al., 2017 | Two China IV vehicles and one Tier 2 vehicle | WLTC | China | -6% | | -22.70% | | | | | | |
| Martins et al., 2014 | compact sedan equipped with a 1.4-L, 8-valve, four-cylinder flexible fuel engine | FTP-75 | Brazil | | | | | | | | | |
| Graham et al., 2008 | Two 2002 LEV 1 LDT and One 2004 ULEV 1 | FTP-75, US06 | Canada | 9% | | -10% | 3% | | 15% | 16% | 5% | 108% |
| Bielaczyc et al., 2013 | One Euro V vehicle | NEDC | Poland | 23% | | 13.30% | 7.80% | -19.70% | -20.80% | | 75% | 5.90% |
| Knapp et al. 2011 | 1977 - 1994 Gasoline vehicles (Total 11 No.s) | UDDS | Alaska | -6.50% | | -8.30% | -0.70% | | -20.10% | -14% | -40.00% | 463% |
| Canakci et al., 2013 | 1.4i SI engine Honda Civic Water-cooled, four-stroke, multi-point injection | running the vehicle at two different vehicle speeds (80 km/h and 100 km/h), and four different wheel powers (5, 10, 15, and 20 kW). The | Turkey | -41% | | -24.20% | -18.50% | | | | | |
| Yao et al., 2011 | 2000 and 2005 passenger cars | FTP-75 | Taiwan | -13% | -11.50% | -10% | -4.40% | | -18% | | 11.20% | 20.60% |
| Czerwinski et l., 2016 | new (Euro 5) flex fuel vehicle Volvo V60 (GDI) | WLTC | Switzerland | -1% | | -16% | -25% | | | | -17.20% | |
| Martini et al., 2009 | Euro IV Ford Focus flexible fuel car | NEDC | Italy | -49% | | -77% | 1% | -26% | 17.90% | -63.60% | -5% | 149% |
| Truyen et al., 2012 | 2001 Fuel Injected Car | ECE15+EUDC | Vietnam | -4% | | -8% | 10.70% | | | | | |
| Munoz et al., 2019 | Euro-5 flex-fuel GDI vehicle (Volvo V60) with a 1.6 L engine | WLTC | Switzerland | -53% | | -75% | -71.23% | | | | | |
| **AVERAGE** | | | | **-16%** | **-21%** | **-16%** | **-7%** | **-17%** | **-15%** | **-15%** | **-20%** | **100%** |

# Thorough Literature Review of Vehicle Emissions Studies with E10

Tailpipe Emissions Adjustments with E10 relative to E0




| | THC | NMHC | CO | NOX | PM | Benzene | 1,3-butadiene | Formaldehyde | Acetaldehyde |
|---|---|---|---|---|---|---|---|---|---|
| Series1 | -16% | -21% | -16% | -7% | -17% | -15% | -15% | -20% | 100% |

# Ethanol and Particulate Matter Emissions Reductions

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# Ethanol and Particulate Matter Emissions

1) The Honda PM model predicts PM formation is correlated with double bonds in gasoline hydrocarbon compound.
   - Ethanol with no double bounds should not contribute to PM

2) A lot of the carcinogenic air toxins including many polycyclic aromatic hydrocarbons are emitted from vehicles in the particulate phase.
   - In general, PAHs with two or three benzene rings existed in the vapour phase, whereas PAHs with more than five rings were observed mainly in the particulate phase (Monaraj et al, 2012).
   - Benzo[a]pyrene one of the most carcinogenic PAHs from vehicle exhaust has 5 fused benzene rings and is mostly in the particulate phase.
   - PAHs in the particulate phase are mostly bound to **PM 2.5 and ultrafine fraction of the airborne particulates** that are reportedly known for their higher health risk

3) Gasoline Direct Injection Engines.
   - GDI engines is dominant modern engine in new cars sold
   - EMPA paper from Switzerland (2016) states ""emissions of selected PAHs were lowered by 67-96% with E10" with GDI engine

# Ethanol and Particulate Matter Emissions: Particulate Matter Index (PMI) Model

- The PMI-based predictive model for PM emissions from gasoline fuels was first proposed by Aikawa et al. (Honda PMI Model)
- It is based on the observed direct correlation between the weight fraction, vapor pressure, and Double Bond Equivalent (DBE) of gasoline fuel and the production of PM emissions.
- The DBE value is a measure of the number of double bonds and rings in the fuel molecule, such as found in olefins, aromatics, and cycloalkanes and is defined as the number of hydrogen atoms which would be required to fully saturate the molecule.
- **Components of fuel with high DBE values were observed to more readily form particulate emissions** in a vehicle with a 2.3L turbocharged engine. The **DBE value for ethanol** and paraffins such as isooctane **is zero**, whereas for aromatics it is in the range of four to seven.
- Thus, aromatic hydrocarbons (which tend to have high DBE values and low vapor pressure) disproportionately contribute to PM formation, and increasing paraffin or ethanol content of the fuel tends to decrease PM.

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# Vehicle Emissions of Toxic Compounds

- Polycyclic Aromatic Hydrocarbons (PAHs)
- Heavy PAHs mostly in particulate phase bound to PM2.5

| Pollutant |
|---|
| Acenaphthene |
| Acenaphthylene |
| Anthracene |
| Benz(*a*)anthracene |
| Benzo(*a*)pyrene |
| Benzo(*b*)fluoranthene |
| Benzo(*g,h,i*)perylene |
| Benzo(*k*)fluoranthene |
| Chrysene |
| Dibenzo(*a,h*)anthracene |
| Fluoranthene |
| Fluorene |
| Indeno(1,2,3,*c,d*)pyrene |
| Naphthalene |
| Phenanthrene |
| Pyrene |

EPA-420-R-16-016
November 2016

# Swiss Study: Ethanol and Gasoline Direct Injection Engines

## Bioethanol Blending Reduces Nanoparticle, PAH, and Alkyl- and Nitro-PAH Emissions and the Genotoxic Potential of Exhaust from a Gasoline Direct Injection Flex-Fuel Vehicle

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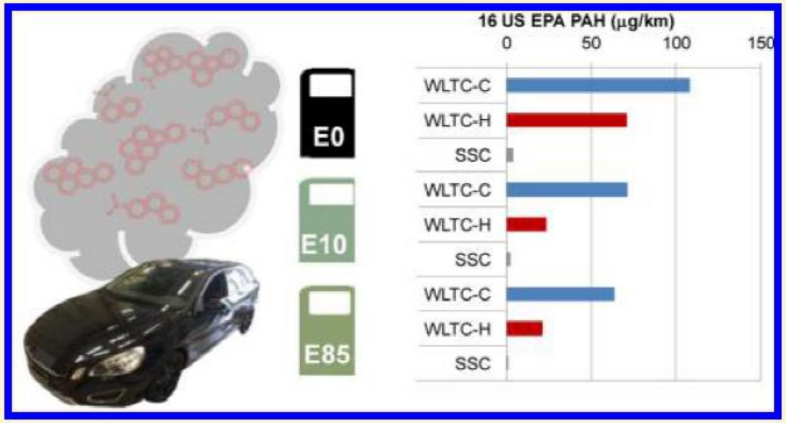
"emissions of selected PAHs were lowered by 67-96% with E10"

Oct 2016

**ABSTRACT:** Bioethanol as an alternative fuel is widely used as a substitute for gasoline and also in gasoline direct injection (GDI) vehicles, which are quickly replacing traditional port-fuel injection (PFI) vehicles. Better fuel efficiency and increased engine power are reported advantages of GDI vehicles. However, increased emissions of soot-like nanoparticles are also associated with GDI technology with yet unknown health impacts. In this study, we compare emissions of a flex-fuel Euro-5 GDI vehicle operated with gasoline (E0) and two ethanol/gasoline blends (E10 and E85) under transient and steady driving conditions and report effects on particle, polycyclic aromatic hydrocarbon (PAH), and alkyl- and nitro-PAH emissions and assess their genotoxic potential.




Particle number emissions when operating the vehicle in the hWLTC (hot started worldwide harmonized light-duty vehicle test cycle) with E10 and E85 were lowered by 97 and 96% compared with that of E0. CO emissions dropped by 81 and 87%, while $CO_2$ emissions were reduced by 13 and 17%. Emissions of selected PAHs were lowered by 67−96% with E10 and by 82−96% with E85, and the genotoxic potentials dropped by 72 and 83%, respectively. Ethanol blending appears to reduce genotoxic emissions on this specific flex-fuel GDI vehicle; however, other GDI vehicle types should be analyzed.

# Korean Study: Ethanol and Gasoline Direct Injection Engines

The impact of various ethanol-gasoline blends on particulates and unregulated gaseous emissions characteristics from a spark ignition direct injection (SIDI) passenger vehicle

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[b] Transportation Pollution Research Center, National Institute of Environmental Research, 42 Hwangyong-ro, Seo-gu, Incheon 22689, Republic of Korea

- "Blending ethanol into gasoline produced a dramatic decrease of particulate emission, because pure ethanol has no aromatic compounds and carbon content lower than that of gasoline."

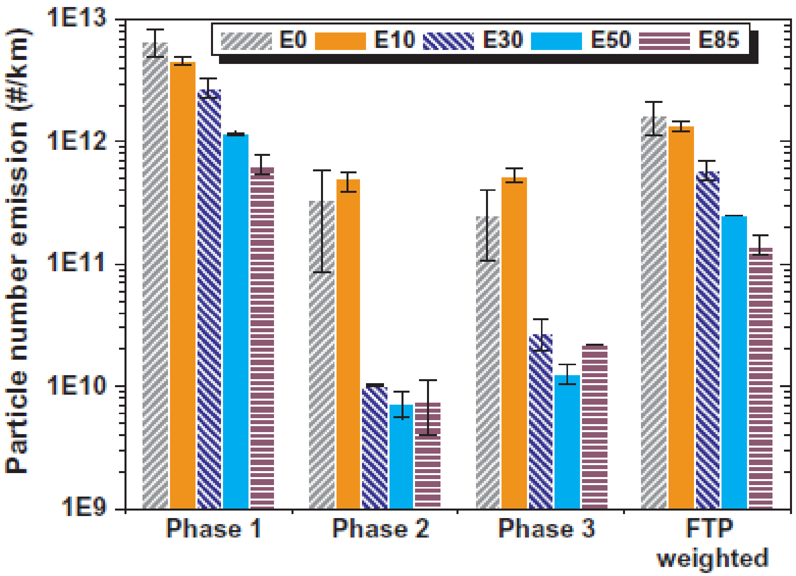


**Fig. 6.** Nano-particle number emissions for the each phase of the FTP-75.

# UIC/US Grains Council 5 Cities Study

# Tailpipe Emissions Modeling

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# Multi Step Modeling Process

| 1 Refining Impact from Ethanol | 2 Emissions Mass Reduction from Ethanol | 3 Emissions Concentration Reduction | 4 Health Risk Reduction from Ethanol | 5 Health Cost Reduction from Ethanol |
| --- | --- | --- | --- | --- |
| Assess Refining Adjustments and Refining Profitability for Gasoline-Ethanol Blends (Aromatics Reductions; Refining Blending Model; Complex Model) | Determine Emissions Reductions from Ethanol –Gasoline Blends by Pollutant (Vehicle Tests, iBEAM, MOVES, Complex Model) | Convert emissions into atmospheric concentratio ns (e.g Box Model) | Apply Cancer Risk and Other Risk Factors to Determine Probability of Extra Cases with Negative Health Impact (e.g. Inhalation Unit Risk Factors, Epidemiological Studies) | Convert extra cases into extra health care costs, mortality, years-of-life-lost, and other metrics |

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# Fuel Sampling

- Intertek Laboratories took 3 fuel samples.
- Used samples to develop gasoline recipe that would meet substantially Korean fuel specs

| TEST ITEM | UNIT | TEST RESULT | METHOD |
|---|---|---|---|
| Regular Gasoline KR201-0012952-2 Mapo-gu, Seoul | | | |
| Sulfur | mg/kg | 4.6 | ASTM D 5453-16$^{\varepsilon 1}$ |
| DVPE at 37.8°C | psi | 10.25 | ASTM D 5191-18 |
| Full carbon chain break down | - | See attached report | ASTM D 6730-01 |
| MTBE | mass % | 11.6 | ASTM D 4815-15b |
| Regular Gasoline KR201-0012952-3 Yeungdeungpo-gu, Seoul | | | |
| Sulfur | mg/kg | 4.2 | ASTM D 5453-16$^{\varepsilon 1}$ |
| DVPE at 37.8°C | psi | 9.17 | ASTM D 5191-18 |
| Full carbon chain break down | - | See attached report | ASTM D 6730-01 |
| MTBE | mass % | 12.0 | ASTM D 4815-15b |
| Regular Gasoline KR201-0012952-4 Guro-gu, Seoul | | | |
| Sulfur | mg/kg | 3.9 | ASTM D 5453-16$^{\varepsilon 1}$ |
| DVPE at 37.8°C | psi | 9.56 | ASTM D 5191-18 |
| Full carbon chain break down | - | See attached report | ASTM D 6730-01 |
| MTBE | mass % | 5.5 | ASTM D 4815-15b |

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# Revised Modeling with 10% MTBE

| | | Seoul | Seoul | Seoul |
|---|---|---|---|---|
| | | MTBE | Ethanol-10 | Ethanol-20 |
| **CHANGE FROM BASE** | | BASE-Seoul | | |
| Gasoline Volume - Relative | BPD | 100.0 | 99.3 | 116.1 |
| Hydrogen from Catalytic Reformer - Relative | MM SCF/day | 53.1 | 47.4 | 28.5 |
| Gasoline Volume Change from Base | | 0.0% | -0.7% | 16.1% |
| Hydrogen Volume Change from Base | | 0.0% | -10.8% | -46.3% |
| Catalytic Reforming Unit Octane (Severity) | RON | 101.0 | 101.0 | 101.0 |
| | | | | |
| **OXYGENATE MIX** | | | | |
| MTBE | vol% | 10.00% | 0.0% | 0.0% |
| ETBE | vol% | 0.0% | 0.0% | 0.0% |
| ETHANOL | vol% | 0.0% | 10.0% | 20.0% |
| TAME | vol% | 0.0% | 0.0% | 0.0% |
| | | | | |
| **GASOLINE PROPERTIES** | | | | |
| RON | | 94.0 | 94.0 | 94.9 |
| MON | | 85.1 | 84.4 | 82.4 |
| (R+M)/2 | | 89.6 | 89.2 | 88.7 |
| Specific Gravity | | 0.7864 | 0.7867 | 0.7654 |
| Oxygen | wt% | 1.7 | 3.5 | 7.2 |
| Sulfur | ppm | 5.7 | 5.8 | 5.2 |
| RVP | psi | 9.7 | 9.7 | 9.7 |
| E200 | vol% | 40.0 | 44.9 | 53.5 |
| E300 | vol% | 79.2 | 78.3 | 83.9 |
| Aromatics | vol% | 10.4 | 10.6 | 9.5 |
| Olefins | vol% | 13.0 | 13.2 | 11.8 |
| Benzene | vol% | 0.46 | 0.47 | 0.42 |

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# Annual Total Vehicle Distance Travelled

1. Project Annual Gasoline Passenger Car Population for each City (based on extrapolation of vehicle saturation levels complemented with literature citations)
2. Account for Electric Vehicle Share
3. Project vehicle distance traveled per gasoline passenger car per year
4. Multiply 1,2,3 to derive total kilometers driven by passenger cars in the city (Annual Vehicle Distance Travelled [km/year])
5. Also: Project Vehicle Retirement over time to derive new vehicles added each year.

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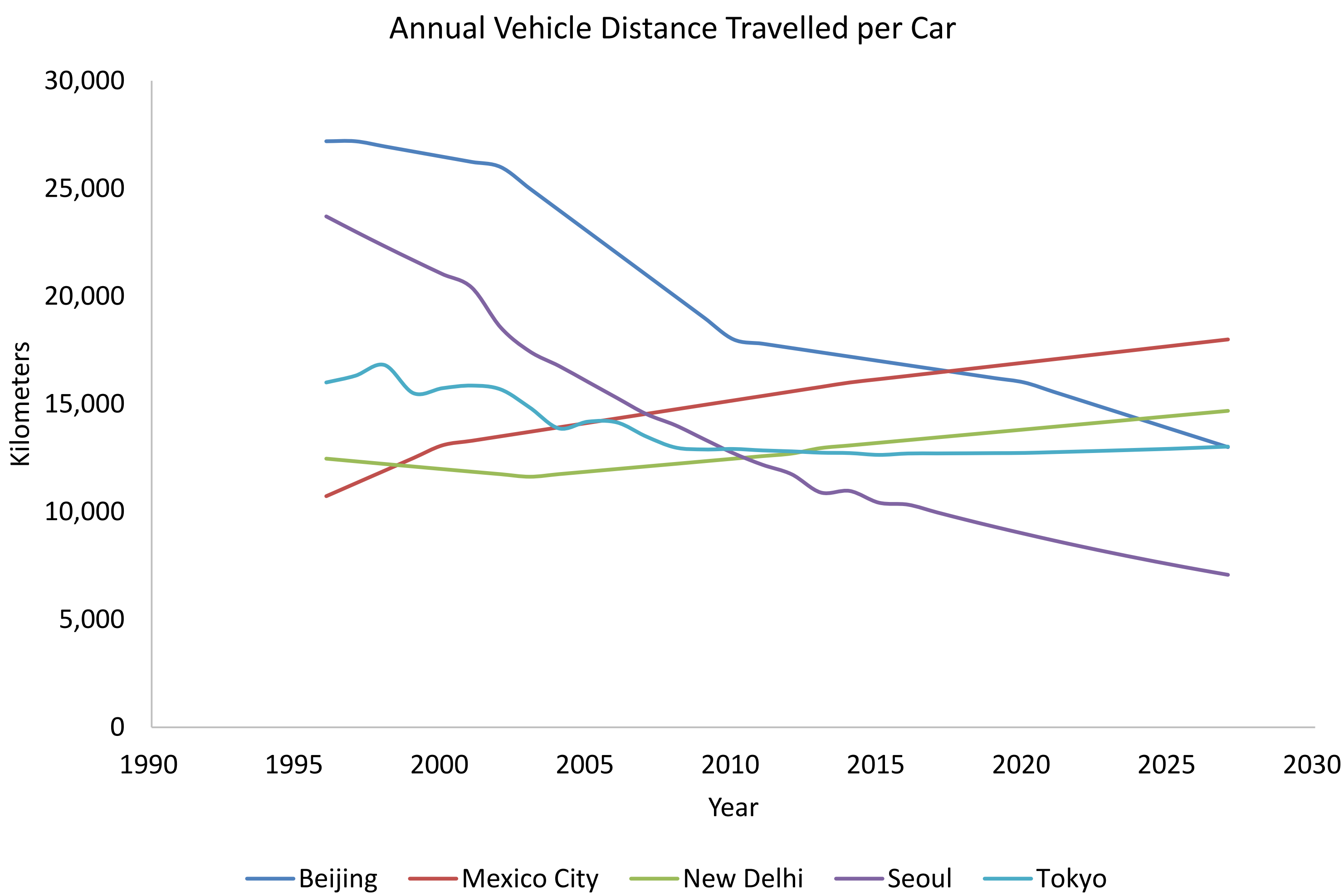
# Annual vehicle distance travelled per car



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# Toxic Air Contaminants (California Air Resources Board)

- "Toxic air contaminant" means benzene, 1,3-butadiene, formaldehyde, or acetaldehyde.
- "In each test, the emission rate of each toxic pollutant shall be multiplied by its relative potency, as shown in the following table, and the four products shall be summed."


| | *Relative Potency* |
|---|---|
| 1,3-butadiene | 1.0 |
| benzene | 0.17 |
| formaldehyde | 0.035 |
| acetaldehyde | 0.016 |

ATTACHMENT A-13; State of California; California Environmental Protection Agency; AIR RESOURCES BOARD; Stationary Source Division CALIFORNIA TEST PROCEDURES FOR EVALUATING SUBSTITUTE FUELS AND NEW CLEAN FUELS IN 2015 AND SUBSEQUENT YEARS; Adopted: March 22, 2012

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# Seoul E10 Emissions relative to MTBE 10

Results are a combination of USA EPA Complex Model and Additional Vehicle Emissions Studies since Complex Model by now is reflective of older vehicles only.

| iBEAM | Seoul | |
|---|---|---|
| GDI Rate | 50% | |
| EV Rate | 7% | |
| | Relative to E0 (%) | Relative to E0 (Total Tonnes) |
| CO | -3.1% | -15,004 |
| THC | -4.9% | -3,369 |
| PM | -0.6% | -1 |
| NOx | 0 | 0 |
| Polycyclics | -2.6% | |
| Weighted Toxins | -7.2% | |

# From Emissions to Health Impacts: Carcinogenicity of Selected Toxics Affected by Ethanol Blends

- Benzene
  - is a well-established cause of cancer in humans. The International Agency for Research on Cancer has classified benzene as carcinogenic to humans (Group 1). Benzene causes **acute myeloid leukemia** (acute non-lymphocytic leukemia), and there is limited evidence that benzene may also cause acute and chronic lymphocytic leukemia, **non-Hodgkin's lymphoma** and multiple myeloma.
    Source: World health organization
- 1,3-butadiene
  - "Studies have consistently shown an association between occupational exposure to 1,3-butadiene and an increased incidence of **leukemia**." Source: https://www.cancer.gov/about-cancer/causes-prevention/risk/substances/butadiene
  - The Department of Health and Human Services (DHHS), IARC, and EPA have determined that 1,3-butadiene is a human carcinogen. Studies have shown that workers exposed to 1,3-butadiene may have an increased risk of cancers of the stomach, blood, and lymphatic system. Source: CDC ATSDR Database
- Formaldehyde
  - **Probable human carcinogen, based on limited evidence in humans**, and sufficient evidence in animals. IARC: Carcinogenic to humans . NTP: Reasonably anticipated to be a human
    Source: CDC ATSDR Database
- Acetaldehyde
  - Based on increased evidence of **nasal tumors in animals** and adenocarcinomas.
    Source: US EPA
  - Note: adenocarcinomas are most prevalent in esophageal cancer, pancreas, prostate cancer.
- Benzo[a]pyrene (BaP); a polycyclic aromatic hydrocarbon PAH
  - The carcinogenicity of certain PAHs is well established in laboratory animals. Researchers have reported increased incidences of skin, lung, bladder, liver, and stomach cancers, as well as injection-site sarcomas, in animals. Animal studies show that certain PAHs also can affect the hematopoietic and immune systems (ATSDR)
  - Tumor site(s): **Lung**, Gastrointestinal, Respiratory
  - Tumor type(s): **Squamous cell neoplasia in the larynx, pharynx, trachea, nasal cavity, esophagus, and forestomach**. (Thyssen et al., 1981). Source: https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=136

# Converting Emissions Mass Reductions to Cancer Risk Reductions

- Convert emissions mass reductions to concentration reductions using atmospheric model (box model)
- Apply Inhalation Unit Risk Factors: excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 microgram/m3 air.

| Pollutant | IUR Factor (risk per ug/$m^3$) | Relative Potency |
|---|---|---|
| **Acetaldehyde** | $2.7 \times 10^{-6}$ | 0.002 |
| **Benzene** | $2.9 \times 10^{-5}$ | 0.026 |
| **Benzo[a]pyrene** | $1.1 \times 10^{-3}$ | 1.00 |
| **1,3-Butadiene** | $1.7 \times 10^{-4}$ | 0.155 |
| **Formaldehyde** | $6.0 \times 10^{-6}$ | 0.005 |


Source: California Environmental Protection Agency

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# Health Impact Relative to MTBE

| Change in Number of Cancer Cases by Pollutant | | | | | |
|---|---|---|---|---|---|
| Acetaldehyde | Benzene | Benzo[a]pyrene | 1,3-Butadiene | Formaldehyde | Total |
| 2.8 | -33.9 | -14.5 | -45.8 | -2.1 | -93.5 |

| Years of life Lost | | | | | |
|---|---|---|---|---|---|
| Acetaldehyde | Benzene | Benzo[a]pyrene | 1,3-Butadiene | Formaldehyde | Total |
| 41 | -488 | -230 | -779 | -31 | -1,487 |

| Treatment costs | | | | | |
|---|---|---|---|---|---|
| Acetaldehyde | Benzene | Benzo[a]pyrene | 1,3-Butadiene | Formaldehyde | Total |
| $195,156 | -$2,375,488 | -$1,012,519 | -$3,202,677 | -$150,282 | -$6,545,810 |

Years of Life Value Saved = Years of Life Lost or Gained x Value of Person Life Year Lost/Gained

## Years of Life Value Saved:

## 1,487 x $150,000 per year = $223,000,000

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# UIC/US Grains Council 5 Cities Study

# GHG Modeling

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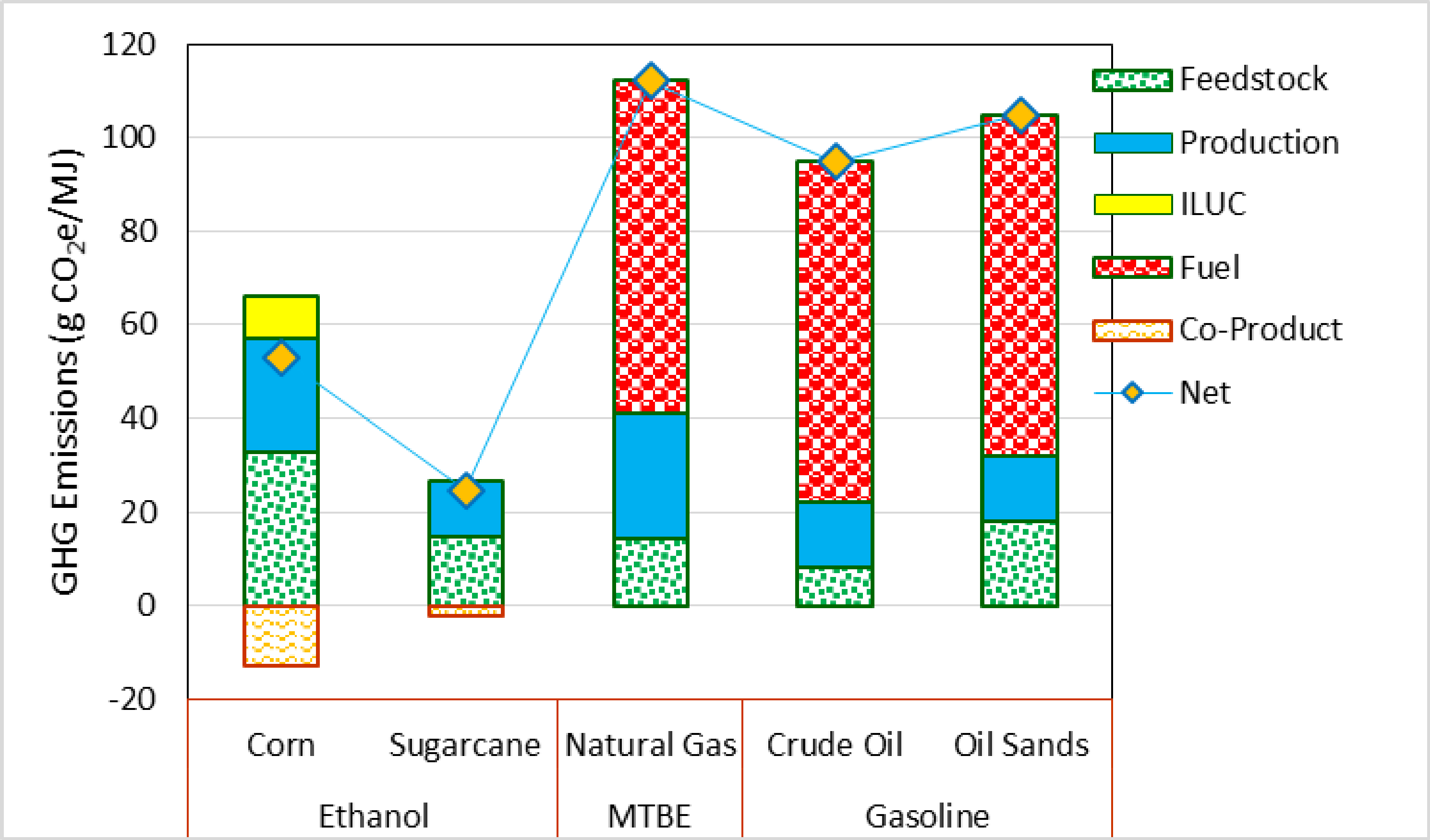
# GHG Models Used

- The UIC ibeam model displays the energy inputs and emissions from corn ethanol over the life cycle from farming to end use. The carbon in the corn is treated as biogenic carbon neutral and the approach follows the methods for ANL's GREET model and the Biograce Model
  - The **GREET model developed by Argonne National Laboratory** is the gold standard for U.S. based life cycle analysis and contains the most up to date information on corn ethanol production. A California version of the GREET model is used for the Low Carbon Fuel Standard. An earlier version was used by the US Environmental Protection Agency for the Renewable Fuel Standard modeling.
  - **The Biograce Mode**l is a European life cycle model that evaluates European fuel pathways under the Renewable Energy Directive (RED). Current Japanese modeling efforts are also closely aligned with the EU RED methodology.

# GHG Emissions of Pure Ethanol vs Pure MTBE

- Corn Ethanol by itself has about half the greenhouse gas emissions of MTBE



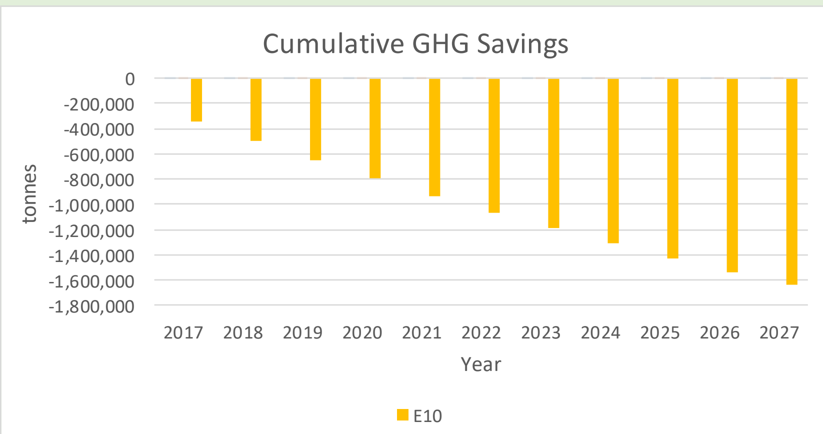
# GHG Savings from E10 relative to MTBE 10

**iBEAM Output**

| GHG | Seoul E10 | Model GREET Allocation |
|---|---|---|

gCO2/MJ

| Current Gasoline Blend | Ethanol | % change (Ethanol to Gasoline) | E10 | % change (E10 to Gasoline Blend) |
|---|---|---|---|---|
| 96.43 | 48.10 | -50.1% | 92.08 | -4.5% |




| | GHG (M tonnes) | | GHG Savings (tonnes) | GHG Savings Cumulative (t) |
|---|---|---|---|---|
| Year | Gasoline Blend | E10 | E10 | E10 |
| 2016 | 3.8 | 3.6 | -172,563 | |
| 2017 | 3.7 | 3.5 | -165,909 | -338,471 |
| 2018 | 3.5 | 3.4 | -159,122 | -497,594 |
| 2019 | 3.4 | 3.2 | -152,262 | -649,856 |
| 2020 | 3.2 | 3.1 | -145,340 | -795,195 |
| 2021 | 3.1 | 2.9 | -138,654 | -933,849 |
| 2022 | 2.9 | 2.8 | -132,223 | -1,066,072 |
| 2023 | 2.8 | 2.7 | -126,062 | -1,192,134 |
| 2024 | 2.7 | 2.5 | -120,150 | -1,312,284 |
| 2025 | 2.5 | 2.4 | -114,469 | -1,426,753 |
| 2026 | 2.4 | 2.3 | -109,029 | -1,535,782 |
| 2027 | 2.3 | 2.2 | -103,814 | -1,639,596 |
| Total: Savings | 36 | 35 | -1,639,596 | -1,639,596 |

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# Japan GHG Modeling

- Uses ETBE as oxygenate as opposed to straight ethanol blending
- In past only used sugarcane ethanol to produce ETBE
- With availability of new corn ethanol efficiency data Japanese scientists assessed GHG reductions from US produced corn ethanol completely independently.
- Result: Opened market to include US corn ethanol as feedstock
  - Japan will allow now 44% of the ethanol feedstock going into ETBE production to come from US corn ethanol (96 million gallons of the total estimated ethanol demand of 217 million gallons)
  - Sustainability will be assessed using ISCC Plus Certification protocol recognized by European Union.

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# Summary Points

- For Korea corn ethanol in gasoline blends…
  - reduces Greenhouse Gas Emissions on a life cycle basis .
    - Higher GHG reductions because in Korea ethanol displaces MTBE and MTBE has a high GHG intensity
    - Continued advances in agriculture including conservation management practices as well as advances in biorefining continuously reduces GHG emissions of corn ethanol relative to gasoline.
  - reduces tailpipe emissions of key pollutants (including volatile organic compounds, **particulate matter**, carbon monoxide, and weighted air toxins)
  - Reduces cancer cases and treatment costs
  - Reduces tailpipe and Greenhouse Gas Emissions right now with the existing vehicle fleet. With electric vehicles we have to wait a long time to realize emissions reductions since the vehicle stock needs to change.
- Sustainability of bioethanol feedstock production can be verified.

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# Appendix

1) Literature Citations on E10 Vehicle Emissions Studies
2) Assumed Exhaust Standards and Fuel/Vehicle Projections for Study
3) ISCC Sustainability Certification

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# Literature on E10 Vehicle Emissions

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# Literature on E10 Vehicle Emissions


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- Seoul: Assumed Exhaust Emissions Standards through Study Time Frame

| | Seoul | | | | |
| --- | --- | --- | --- | --- | --- |
| | Exhaust Emission Factors (g/km) | | | | |
| **Year** | CO | THC | NOx | PM | HC Evap |
| **1996** | 2.11 | 0.4 | 0.25 | 0.001563 | 2.00 |
| **1997** | 2.11 | 0.4 | 0.25 | 0.001563 | 2.00 |
| **1998** | 2.11 | 0.4 | 0.25 | 0.001563 | 2.00 |
| **1999** | 2.11 | 0.32 | 0.25 | 0.001563 | 2.00 |
| **2000** | 2.11 | 0.32 | 0.25 | 0.001563 | 2.00 |
| **2001** | 2.11 | 0.32 | 0.25 | 0.001563 | 2.00 |
| **2002** | 2.11 | 0.16 | 0.25 | 0.001563 | 2.00 |
| **2003** | 2.11 | 0.16 | 0.25 | 0.001563 | 2.00 |
| **2004** | 2.11 | 0.16 | 0.25 | 0.001563 | 2.00 |
| **2005** | 2.11 | 0.16 | 0.25 | 0.001563 | 2.00 |
| **2006** | 2.11 | 0.16 | 0.25 | 0.001563 | 2.00 |
| **2007** | 2.11 | 0.16 | 0.25 | 0.001563 | 2.00 |
| **2008** | 2.11 | 0.16 | 0.25 | 0.001563 | 2.00 |
| **2009** | 2.11 | 0.047 | 0.031 | 0.001563 | 2.00 |
| **2010** | 2.11 | 0.047 | 0.031 | 0.001563 | 2.00 |
| **2011** | 2.11 | 0.047 | 0.031 | 0.001563 | 2.00 |
| **2012** | 2.11 | 0.047 | 0.031 | 0.001563 | 2.00 |
| **2013** | 1 | 0.047 | 0.031 | 0.001563 | 1.20 |
| **2014** | 1 | 0.047 | 0.031 | 0.001563 | 1.20 |
| **2015** | 1 | 0.047 | 0.031 | 0.001563 | 1.20 |
| **2016** | 1 | 0.047 | 0.02 | 0.001563 | 1.20 |
| **2017** | 1 | 0.047 | 0.02 | 0.00125 | 1.20 |
| **2018** | 1 | 0.027 | 0.02 | 0.00125 | 0.95 |
| **2019** | 1 | 0.027 | 0.02 | 0.00125 | 0.95 |
| **2020** | 1 | 0.027 | 0.02 | 0.00125 | 0.47 |
| **2021** | 1 | 0.025 | 0.01 | 0.000938 | 0.47 |
| **2022** | 1 | 0.01 | 0.01 | 0.000938 | 0.35 |
| **2023** | 1 | 0.01 | 0.01 | 0.000938 | 0.35 |
| **2024** | 1 | 0.01 | 0.01 | 0.000938 | 0.35 |
| **2025** | 1 | 0.01 | 0.01 | 0.000938 | 0.35 |
| **2026** | 1 | 0.01 | 0.01 | 0.000938 | 0.35 |
| **2027** | 1 | 0.01 | 0.01 | 0.000938 | 0.35 |

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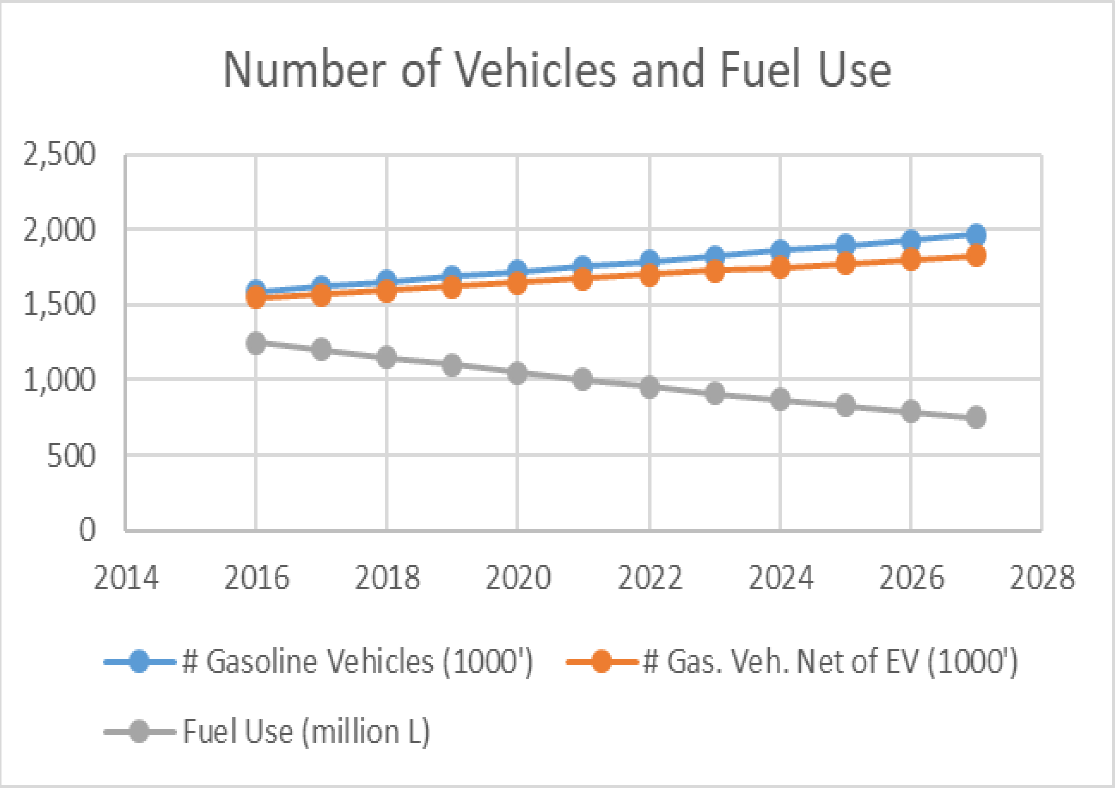
# Seoul: Gasoline Vehicle, Fuel Use, Fuel Economy (FE) and Vehicle Distance Travelled (VDT) Projections

| Year | # Gasoline Vehicles (1000') | # Gas. Veh. Net of EV (1000') | Fuel Use (million L) | FE (L/100 km) | VDT (million km/year) |
|---|---|---|---|---|---|
| 2016 | 1,590 | 1,546 | 1,248 | 7.82 | 15,967 |
| 2017 | 1,622 | 1,572 | 1,200 | 7.66 | 15,664 |
| 2018 | 1,655 | 1,597 | 1,151 | 7.49 | 15,367 |
| 2019 | 1,689 | 1,623 | 1,102 | 7.31 | 15,076 |
| 2020 | 1,722 | 1,648 | 1,051 | 7.11 | 14,790 |
| 2021 | 1,756 | 1,674 | 1,003 | 6.91 | 14,509 |
| 2022 | 1,791 | 1,700 | 957 | 6.72 | 14,233 |
| 2023 | 1,826 | 1,726 | 912 | 6.53 | 13,962 |
| 2024 | 1,861 | 1,752 | 869 | 6.35 | 13,696 |
| 2025 | 1,896 | 1,778 | 828 | 6.16 | 13,435 |
| 2026 | 1,931 | 1,803 | 789 | 5.99 | 13,178 |
| 2027 | 1,967 | 1,829 | 751 | 5.81 | 12,927 |



# ISCC Certification Approach for Japan

Dr Norbert Schmitz, Managing Director, ISCC System GmbH
7th ISCC Regional Stakeholder Committee North America, Las Vegas, 27 November 2018

ISCC
International Sustainability & Carbon Certification

# New biofuel mandate in Japan for 2018 – 2022 (I)

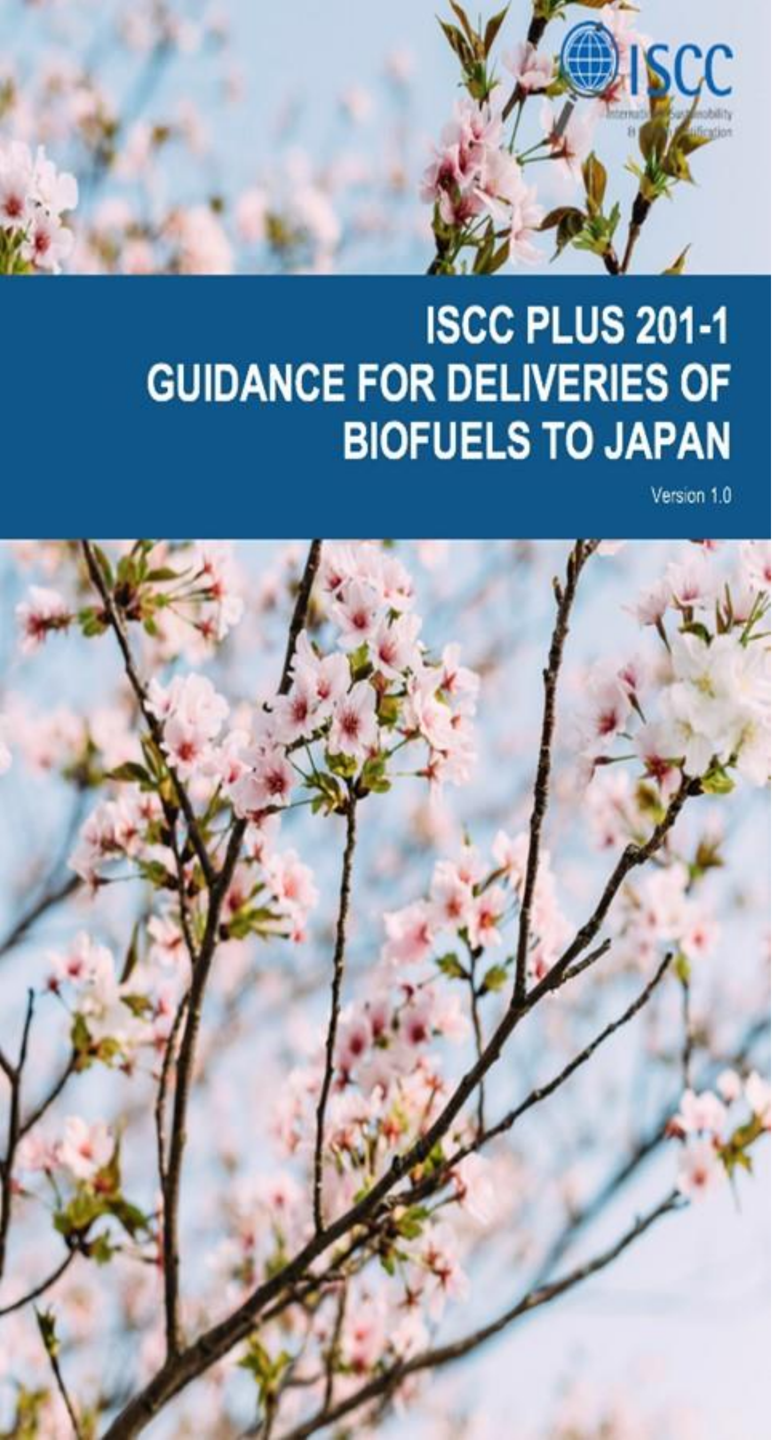
- ISCC PLUS is recognised by the Japanese government to **verify compliance with sustainability requirements** for biofuels
- The recognition was announced by METI (Japanese Ministry of Trade and Industry) in the framework of presenting the **new biofuel mandate for Japan for 2018 – 2022**
- Most important changes in the new mandate:
  - GHG emission reduction target for ethanol **raised from 50% to 55%**
  - Markets opened for **U.S. corn-based ethanol** (previously, only Brazilian sugarcane-based ETBE and ethanol allowed)
  - Rationale is to **lower the overall sourcing costs** and **improve energy security** of Japan

ISCC International Sustainability & Carbon Certification

# Specific provisions for deliveries of ethanol to Japan – Sustainability requirements

**Sustainability criteria**

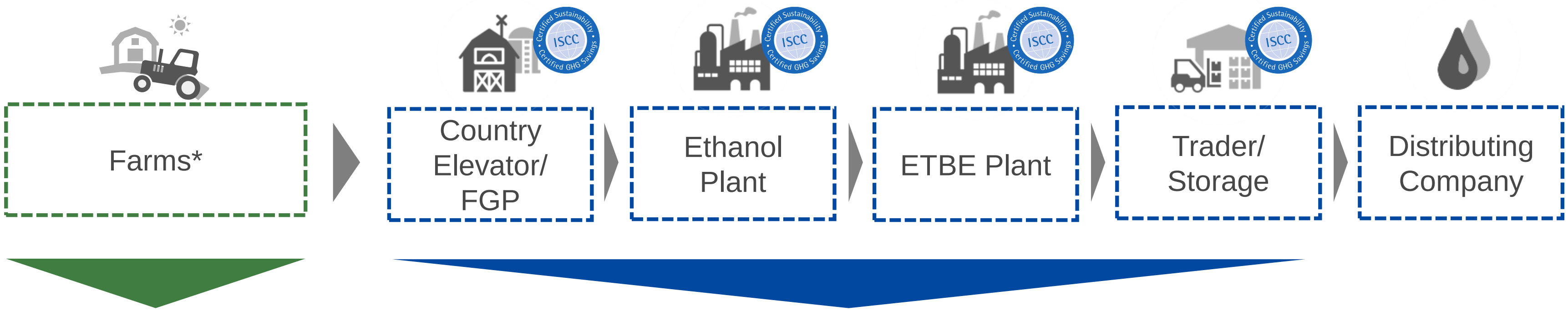
- Exclusion of land use change
- Application of mass balance approach and traceability in supply chains
  - As means to prove compliance certification, such as ISCC, can be applied
- Effects on food competition and biodiversity
  - For compliance other methods than certification can be applied, e.g. contractual agreements




# ISCC certification approach for Japan

- ISCC has set up a guidance document for deliveries of biofuels to Japan
- Key points of the guidance document:
  - Certification of whole supply chain under ISCC PLUS
  - GHG default values provided by Japan to be applied
  - Specific statements on sustainability declarations
- **Options for ISCC EU** certified operators:
  - Operators along the supply chain certified under ISCC EU can **easily obtain an additional ISCC PLUS** certificate
  - The certification body can issue the ISCC PLUS certificate on the basis of the existing ISCC EU audit documentation of the respective scopes

# Certification of whole supply chain under ISCC PLUS. Example corn ethanol supply chain – LUC has to be excluded




1 Protection of biodiversity
2 Preservation of carbon sinks
3 Good agricultural practices
4 Human and social rights
5 GHG emissions

1 Traceability
2 Chain of custody
3 GHG emissions

* Covered under certification of country elevator

# ISCC in the USA: 76 ISCC certificates have been issued for ethanol plants

Selection

Green Plains Partners LP
ARKA
Cargill
Marquis Energy
Big River Resources
Illinois Corn Processing
cie
Plymouth Energy LLC
Little Sioux Corn Processors
LDC Louis Dreyfus Company
Siouxland Energy Cooperative
Absolute Energy, L.L.C.
Creating fuel for our future.
POET Human + Nature
Quad County Corn Processors
Platinum ethanol
Glacial Lakes Corn Processors "Let's Add Value!"
Conestoga energy partners, LLC
Granite Falls Energy LLC
Patriot Renewable Fuels, LLC

ISCC International Sustainability & Carbon Certification

# ISCC has a strong presence in Asia and was applied in the Republic of Korea since 2011

- **Already in 2011,** immediately after the recognition by the European Commission, first certificates were issued **in the Republic of Korea**
- In total **65** certificates were issued **in Korea** since then
  **7** certificates are currently valid
- Main feedstock in Korea is **Used Cooking Oil** (UCO)

- Approx. **50%** of all certificates in Asia deal with **waste & residues**
- In total **3,900+** certificates were issued **in Asia**
  **730+** certificates are currently valid

- In total **20,000+** certificates were issued **worldwide**
  **3,450+** certificates are currently valid