Transportation Policies and the Future of Low-C Transportation

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Outline

• Transportation fuel use and GHG emissions are increasing at a rapid rate
  – Needs for transportation policies toward a low carbon future

• Federal and regional/state transportation policies
  – California’s Low Carbon Fuel standard

• Needs for better forecasting and policy evaluation tools
Travel Demand (Passenger-KM Traveled, PKT) is Projected to Grow Substantially Over the Next 4 Decades

Travel demand in 2005

Per capita Annual Travel (000 PKT)

Per capita PPP GDP (2005 US$)

Total Travel (Trillion PKT/year) 40 60 80

Scenarios 2005 SSP1 SSP2 SSP3 SSP5

Mishra et al. (2014)
Travel Demand is Projected to Grow Substantially Over the Next 4 Decades, Especially in Developing Countries.

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**Travel demand in 2050**

- **Per capita Annual Travel (100 PKT)**
  - 25
  - 20
  - 15
  - 10
  - 5

- **Per capita PPP GDP (2005 US$)**
  - 20
  - 40
  - 60
  - 80

- **Total Travel (Trillion PKT/year)**
  - 40
  - 60
  - 80

**Scenarios**
- 2005
- SSP1
- SSP2
- SSP3
- SSP5

*Mishra et al. (2014)*

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[Image: Diagram showing travel demand in 2050 with categories for developed and developing regions, along with per capita GDP and annual travel in trillion PKT/year.]
Fuel Consumption and CO$_2$ Emissions will Rise Substantially in Developing Countries
Fuel Consumption and CO₂ Emissions will Rise Substantially in Developing Countries

- Developed countries:
  - More efficient vehicles
  - Advanced vehicle technology
  - Saturation of travel demand/capita

Mishra et al. (2014)
Fuel Consumption and CO₂ Emissions will Rise Substantially in Developing Countries

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**Developing countries:**
- Decreasing share of public mode
- Increasing share of aviation & LDV
- Upsizing of LDV
- Increasing travel demand/capita

Mishra et al. (2014)
Today’s Transportation Almost Entirely Relies on Products of Crude

2005 Transportation
Total GHG = 6900 MMtCO₂e
Trans sector WTW = 14%
Trans sector CI = 478 gCO₂e/MJ useful energy

Yeh et al. (2013)
Absent Climate Policies, Huge Global Investment Needed to Meet Increased Demand for Crude and “Unconventional” Energy Carriers

Transportation BAU (2100)
Total GHG = 19500 MMtCO₂e
Trans sector WTW = 19.2%
Trans sector Cl = 320 gCO₂e/MJ useful energy

Technology improvement lowers pathway Cl

UCDAVIS
SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

Yeh et al. (2013)
Absent Climate Policies, Huge Global Investment Needed to Meet Increased Demand for Crude and “Unconventional” Energy Carriers

Increased demand for crude and “unconventional” energy carriers, including CTL, biomass to liquid (BTL), GTL, and hydrogen dampen improvements in technology efficiency and lifecycle CI.
Low-Carbon Transportation Can Be Achieved Under a Strong Climate Policy

RCP4.5 Advanced Tech no CCS(2100)
Total GHG = 8200 MMtCO₂e
Trans sector WTW = 26.3%
Trans sector CI = 141 gCO₂e/MJ useful energy

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Lower Carbon Fuels

More efficient vehicles Lower VMT

Yeh et al. (2013)
Today’s Transportation Fuels/Vehicles

Primary energy supply:
- Oil resources
- Unconventional: oil sands
- Corn, soybean, waste oil

Conversion sector:
- Refinery/Gas
  - Refinery
- Other Liquid Fuel
  - Ethanol
  - Renewable/bio-diesel

Transport:
- Gasoline/Diesel vehicle
- Aviation, shipping, ...
Potential Future Transportation Fuels/Vehicles

Diagram showing potential future transportation fuels/vehicles:

- Primary energy supply:
  - Coal resources
  - Oil resources
  - Unconventional: oil shale liquid, oil sands
  - Gas resources
  - Unconventional: shale gas, coalbed methane
  - Nuclear
  - Corn, soybean, energy crops, ag/forest residues, municipal waste, grease, tallow, waste oil, algae
  - Area wind
  - Area solar
  - Geothermal

- Conversion sector:
  - Refinery/Gas:
    - Refinery
    - Gas processing
  - Other Liquid Fuel:
    - Ethanol
    - Renewable/bio-diesel
    - Coal/Gas-to-Liquid
    - Fischer-Tropsch Poly-gen
  - Elec sector:
    - Coal/Gas PP/CHP
    - Solar PV/thermal
    - Biomass PP/CHP
    - Nuclear
    - Wind converter
  - Hydrogen:
    - Electrolysis
    - SMR
    - Gasification
    - Liquefaction

- Transport:
  - Gasoline/Diesel vehicle
  - Natural gas vehicle
  - Hydrogen fuel cell
  - Electric vehicle
  - Plug-in hybrid vehicle
  - Aviation, shipping, ...
Why Transportation is Unique and Difficult to Decarbonize

- Market failures
  - Inadequate R&D, and pollution externalities
- Unique market conditions and barriers
  - Coordination (network effects) among fuel producers, vehicle manufacturers, and fuel distributors (chicken and egg problem)
  - Conservative (inelastic) consumer behavior
  - Large energy security externalities
  - Long time horizons needed for return on fuel infrastructure investments
  - Lack of fuel-on-fuel competition
  - Diffuse nature of the biofuel industries
  - Market power of oil companies.
Existing Policies aim at Improving the Sustainability of Transportation

- **Vehicle efficiency**
  - CAFE/GHG performance standards
- **Fuel carbon intensity**
  - Renewable Fuel Standard (RFS), Low Carbon Fuel Standard (LCFS)
- **Advanced fuel/vehicle technology**
  - Zero-emission vehicle (ZEV) program
  - Energy infrastructure policies
- **Better VMT management**
  - Pricing of roads and vehicle use, land use mgt, public transport (plus systems mgt, eco-driving)
Key Features of California’s Low Carbon Fuel Standard

- Administered by California Air Resources Board
  - University of California, Berkeley and Davis provided policy blueprints by the request of the Gov.
- Regulated parties are transport energy suppliers
  - Oil providers, plus others who want to earn credits, such as biofuel, electricity, NG and H₂ providers
- Requires 10% reduction in carbon intensity (gCO₂-eq/MJ) by 2020
- Carbon intensity measured as lifecycle emissions
- Includes all fuels (oil, biofuels, electricity, natural gas, hydrogen, etc)
- Allows trading of credits
Legal Status Becoming More Secure (California Mostly Won Lawsuits)

1. **Federal Court**: Oil and corn ethanol companies alleged California was unconstitutionally regulating beyond its borders ("extraterritorially") and was discriminating against **interstate commerce** (ie, ethanol and oil producers outside California)
   - In Sept 2013, appeals court reversed lower court and unanimously upheld the LCFS as constitutional. It required some additional fact finding and a freezing of the LCFS target for one year.

2. **California State Court**: Ethanol company (POET) alleged that CARB violated the California Environmental Quality Act by not preparing an adequate environmental analysis when it adopted the LCFS (dealing with higher NOx emissions from biodiesel), and also claiming that they were unfairly penalized by having to include indirect (land use) emissions
   - In June 2013, an appeals court ruled that CARB did not conduct a full environmental review before adopting LCFS and needed to fix its review, but that the LCFS "will continue to operate".

*In both state and federal cases, the judges spent considerable time and effort discussing CARB’s mandate to implement AB 32 and the complexity and importance of California’s LCFS.*
LCFS Is Modestly Successful, So Far

- Excess credits generated (and increasing) every quarter
  - 46% extra credits generated (relative to LCFS requirements) in first half of 2013 (and 61% extra credits total since 2011)

- Biofuels are being decarbonized
  - Carbon intensity declined for all biofuels except sugarcane etoh
  - Higher-carbon ethanol (90+ g/MJ) dropped from >1/2 of ethanol mix in 2011 to <1/4 in first half of 2013
  - Some of this “decarbonization” likely due to shuffling

- Increasing quantities of very low-carbon, waste-based fuels

- Credit prices, volumes, and trades trending up
  - $16/MT in 2012 to $80/MT in November 2013 (and drop to $50-60 at end of December 2013, now at around $35)
Innovations in Carbon Intensity of LCFS Pathways

Carbon intensity of feedstock/fuel combinations in use in California’s LCFS as of November 2013.

UC Davis
SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

Yeh and Witcover (2014)
Excess Credits Being Generated (Targets Exceeded for 2011-2013) Alternative Fuels Energy/Volumes Increased
LCFS Credit Prices Increased and Came Back Down Due to Over-compliance from the Freezing of the Standard due to the Lawsuit

Caution in interpreting LCFS credit prices

- Because stringency of the LCFS increases over time and credit price is spread over entire fuel pool....

- $80/tonne CO2 translates to:
  - 2 cents per gallon in 2015
  - 8 cents per gallon in 2020
Forecasting Transportation Energy Use, GHG Emissions, Policy Impacts: Better Forecasting Tools Needed

• Address interactive effects of policies
• Recognize changes in consumer behaviors and preferences
  – Vehicle choices, better VMT scenarios, mode choices, multi-modal travels, the new sharing economy
  – More data is becoming available with the help of information and communication technology (ICT)
Direct and Possible Interactive Effects of Specific Policy Instruments

<table>
<thead>
<tr>
<th>Policy instrument</th>
<th>Direct Impacts</th>
<th>Interactive Impacts with the Other Policies (Policies Affected)</th>
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</thead>
<tbody>
<tr>
<td>Zero emission vehicle (ZEV) program</td>
<td>Number of ZEVs adopted</td>
<td>Increased use of electricity and hydrogen (LCFS, RPS, AB118, SB1505)</td>
</tr>
<tr>
<td>CAFE standard</td>
<td>Fuel efficiency of cars and trucks</td>
<td>Reductions in gasoline and diesel use (LCFS)</td>
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<tr>
<td>Renewable Portfolio Standard (RPS)</td>
<td>Lower GHG emissions from the electric sector</td>
<td>Reduce the carbon intensity of electricity (LCFS), lower the price of carbon credits (LCFS, Cap-and-Trade)</td>
</tr>
<tr>
<td>AB118</td>
<td>Investment incentives on the deployment of low-carbon fuels and infrastructure</td>
<td>Increase the adoption of low-carbon fuels/vehicles (ZEV, LCFS)</td>
</tr>
<tr>
<td>Cap-and-Trade</td>
<td>Increase the cost and reduce the consumption of fossil energy</td>
<td>Increase the price of fossil energy and lower the credit prices of the LCFS</td>
</tr>
</tbody>
</table>

* AB118: Alternative and Renewable Fuel and Vehicle Transportation program administered by the California Energy Commission to develop and deploy alternative and renewable fuels and advanced transportation technologies.

- **Understanding the impacts of a specific policy requires a good understanding of what happens to the entire SYSTEM**
MA³T (Market Allocation of Advanced Automotive Technologies), nested multinomial logit model developed by Oak Ridge National Laboratory
Illustrative example of Station Availability & Cost of Refill

- As numbers of gasoline vehicles decrease, cost of refueling, and disutility of model availability could go up.
• Comprehensive and complementary transportation policies are needed to address the unique challenges in the transportation sector;
• State policies especially California are driving the national agenda in fuels, vehicle and VMT policies;
• Better forecasting and policy evaluation tools are needed to address the insufficient attention to evaluate:
  • Increasing interactive effects between policies
  • Changes in consumers’ behaviors and preferences
• Focus on challenges of 2020-2030 transitions.

Lower Carbon Fuels

More efficient vehicles
Lower VMT