California's Energy Future Study

Co chairs:
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CCST Council Mtg

Goals of our study

- Assess the *technology* gaps in meeting 2050 goals of the Executive Order limiting emissions to 80% below 1990 levels
- Identify policies implied by the analysis that would help to fill the gaps
- Identify dead-ends vs. stepping stones in current policy and approaches
- Identify current “breakthrough” research in the state and beyond that might help to fill the gaps
- Comment on remaining gaps that might (must?) be filled by behavior change

Funding

- $100K Bechtel Foundation
- $50K CEC
- $25K CARB
- $? CAPUC pending

Four Key Questions that will determine our energy future:

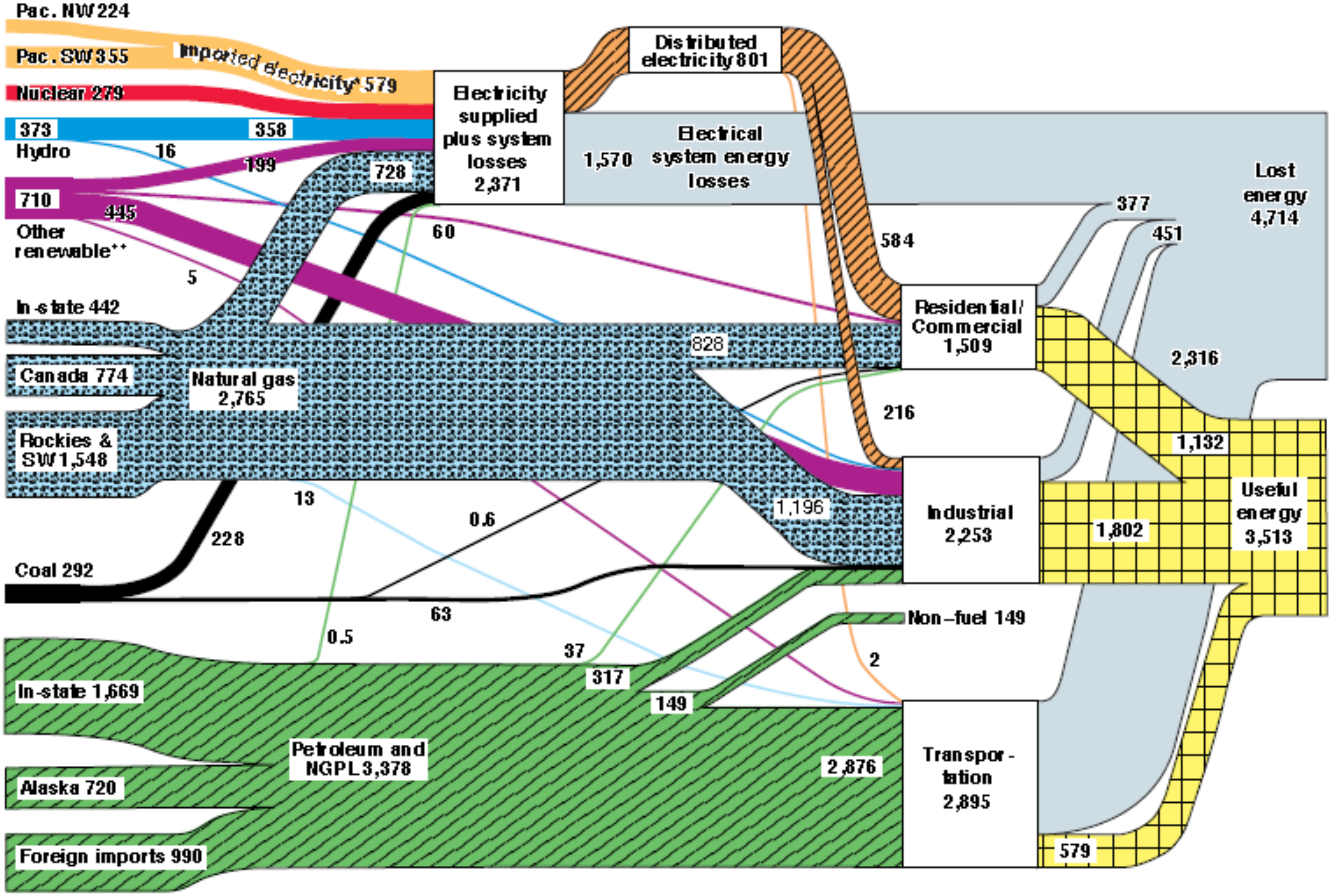
1. How much can we control demand?
2. How will we manage transportation and heat?
3. How can we de-carbonize electricity?
4. How can we de-carbonize fuel?

Gap Analysis Procedure

- Develop bounding cases
- Stress test technologies against bounding cases
- Harmonize stress tests
- Create 2050 portraits
- Assess technology gap against 2050 portraits

California Energy Flow Trends– 1999

Net Primary Resource Consumption ~8375 Trillion Btu (8.375 Quads)



Sources: U.S. Department of Energy's Energy Information Administration and California Energy Commission.
*Electricity flowing into the California control areas: CAISO, LADWP, and IID.
**Other renewable includes geothermal, wood and waste, solar, and wind.

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Bounding cases

Bounding Cases Meeting 2050 Requirements	**Sources of Energy** (negative or positive)			
Transportation and heat managed with:	**Extreme demand-side efficiency:**	**Nuclear Power**	**Fossil with carbon management**	**Renewable: wind, solar, geothermal, biomass *etc*.**
Electricity: 2050 energy demand BAU growth in electricity +Maximally electrified Transportation and 100% electric heat*	**CASE 1A** 90% reduction in 2050 energy use	**CASE 2A** 100% of DELIVERED electricity	**CASE 3A** 100% of delivered electricity	**CASE 4A** 100% of delivered electricity
H_2: BAU growth in electricity + Maximal use of H_2 in transportation and 100% H_2 heat*	**CASE 1B** 90% reduction in 2050 energy use	**CASE 2B** 100% of DELIVERED electricity plus hydrogen	**CASE 3B** 100% of DELIVERED electricity plus hydrogen	NA
Hydrocarbons: BAU use of HC's for transportation and heat	**CASE 1C** 90% reduction in 2050 energy use	NA	**CASE 3C** Sequester an amount of CO2 to offset 90% of fuel related emissions	**CASE 4C** 90% of heat and transportation from carbon-neutral biomass

Primary technologies stressed

1	Extreme efficiency	Demand-side technology, including smart grid, highly efficient vehicles, building and industrial technology
2	Nuclear power	Nuclear power
3	fossil fuel based with carbon management	Carbon capture and storage (CCS)
4	renewable sources	Wind, solar, geothermal, biomass electricity, energy storage, transmission
A	electric vehicles and heat(applies to cases 2,3, and 4)	Electric drive train vehicles, batteries
B	hydrogen transportation and heat (applies to cases 2,3, and 4)	Hydrogen fuel cell vehicles and hydrogen production
3C	Fossil fuel transportation and heat with carbon manageme	Air capture with CCS, decarbonized fuel production from fossil fuels with CCS or other offsets
4C	Renewable energy-based transportation and heat	Biofuels

fig 1

Nuclear

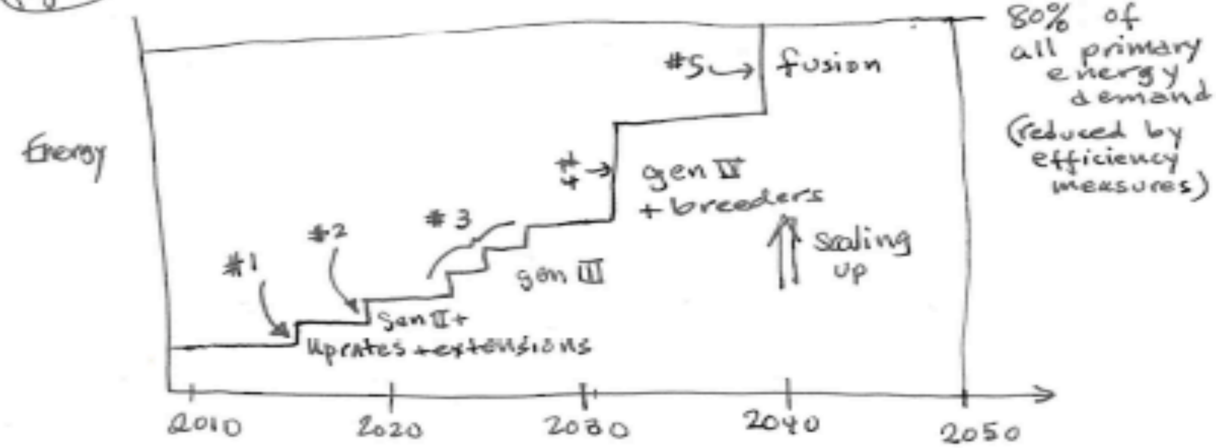
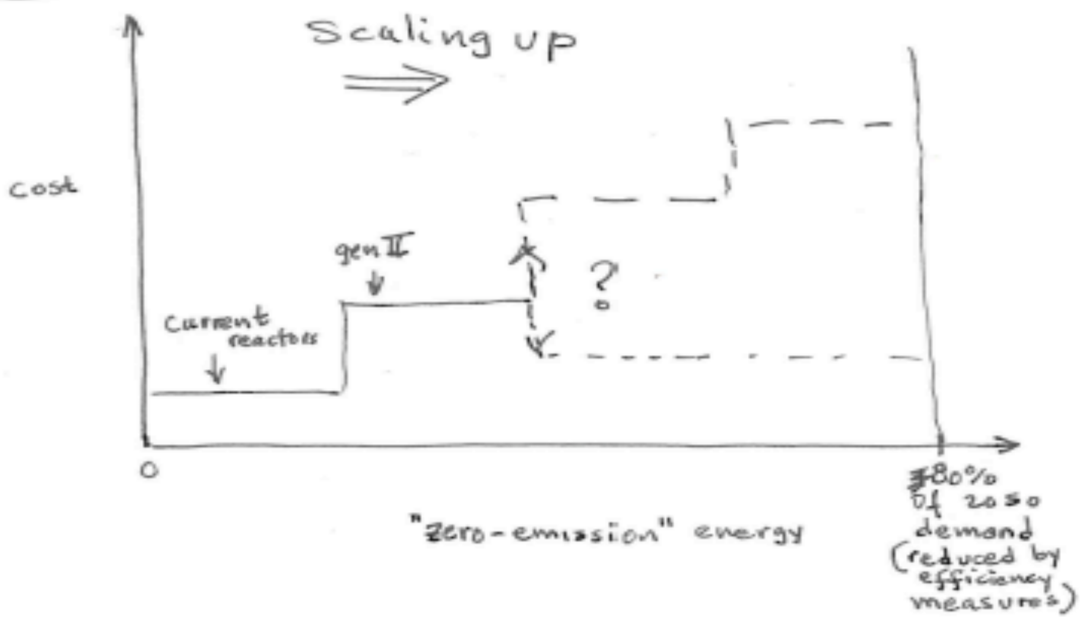


fig 2



Economic vs technical gap

- Not technology gaps:
  - Technology is known and currently deployed and deployable
  - We could scale up because there are clear known economies of scale
- Technology gaps:
  - We need known investment in technology to make the technology deployable (ie economical)
  - We need entirely new and possibly unknown technology, and if we get this technology we could deploy more
  - Even new technology is unlikely to fill the gap

Making realistic portraits of the energy system in 2050

- Will require judgment
- Will be a lower cost, lower obstacle combination of the bounding cases
- May be more than one

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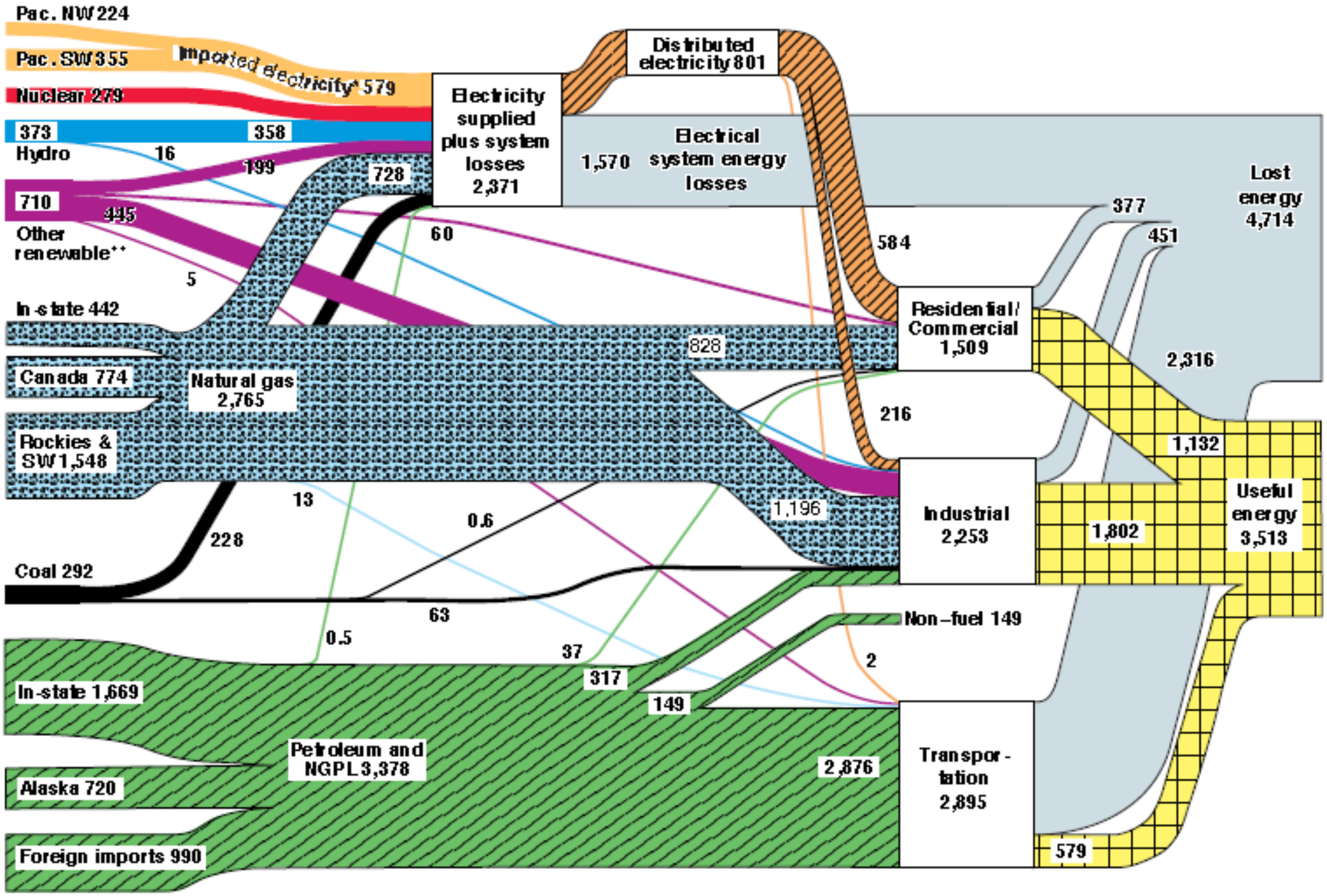

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Realistic energy portraits

- EPRI has a report showing that electricity costs will be ~twice as high if CCS and nuclear are not available in 2050
- E3 Stock rollover report will suggest a portfolio of nuclear, CCS and renewables is optimal

Rough Schedule

- Bounding case definition completed
- Bounding case analysis in November
- Realistic energy portraits in December
- Policy implications and conclusions January

Extra slides

United States Energy Flow in 2007: ~105,379 TJ

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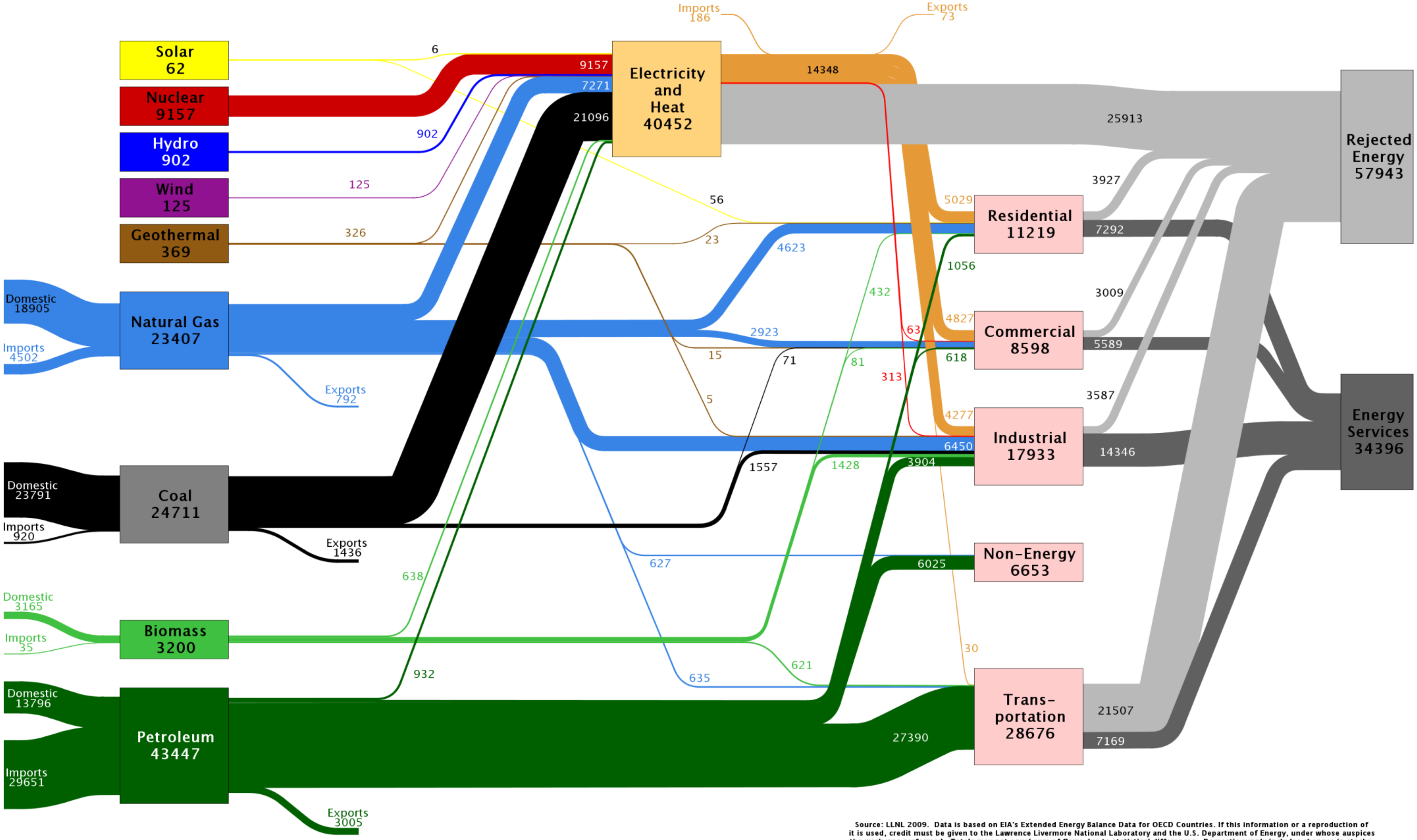

Source: LLNL 2009. Data is based on EIA's Extended Energy Balance Data for OECD Countries. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the U.S. Department of Energy, under whose auspices the work was performed. Totals may not equal sum of flows due to statistical differences. Domestic supply includes changes in stocks. Biomass includes the renewable portion of waste and petroleum includes the non-renewable portion of waste. Rejected energy from Electricity includes transmission losses. Industry includes energy used in coal, oil and gas extraction and processing as well as agriculture, forestry and fishing. Transportation includes fuel delivered to international aviation and marine bunkers. LLNL-MI-410527.

Gap evaluation rules so far:

1. Economic vs technical gap
2. Global context - Imports allowed
3. Costs can increase or decrease over current costs
    1. Resource limitations
    2. Economies of scale

2. **The context for scaling up technology in California should be global.**

- Assume the rest of the world is scaling the same technology up as Calilfornia
- So if you are scaling up nuclear power, you need to assume the rest of the world is scaling it up too and any issues related to scarcity have to be globally considered.
- For regionally specific resources, eg wind, the wind farm sites are clearly not competing globally, but the generators are.

Resource assessment:

- Estimates of resource availability can be controversial. For example,
  - the last thorough geothermal resource assessment was done before we really understood plate tectonics or we had binary technology for low-temperature resources.
  - Wind surveys are incomplete.
  - Uranium is another example where some think we will be resource limited and others don't.
- We think we should **limit the assumptions about resources and as much as possible use referenced data**
- **AEF IS NOW AVAILABLE** and gives 2030 potential for technologies
- If you wish to speculate beyond published data we are asking groups to **convince us that the estimates of resources are "VERY LIKELY**".