Reducing Hawaii's Oil Dependence and Greenhouse Gas Emissions

U.S. Department of Energy
State of Hawaii

Discussion document for HCEI working groups

June 17-20, 2008

PROJECT OBJECTIVE AND APPROACH

Objective: Develop a comprehensive, objective, consistent fact base to inform economically sensible approaches for reducing Hawaii's crude oil dependence and greenhouse gas (GHG) emissions

We **did** look at:

- All energy uses (i.e., stationary, mobile, etc.)
- Man-made emissions within the state of Hawaii – excluding international aviation and marine transportation
- Opportunities available under $50/ton of CO_2e
- Technologies and approaches with predictable costs and development paths
- Resource costs – i.e., net capital, operating and maintenance impacts

We **did not** look at:

- "Imported" carbon
- Policy implementation or transaction costs
- Dynamic impact of a carbon price (e.g., carbon tax or cap)
- Changes in consumer lifestyles or behavior (e.g., drive less, consume less)
- Broader societal costs or benefits (e.g., impact of mitigating climate change, welfare, improved energy security)

Source: McKinsey

Executive Summary

EXECUTIVE SUMMARY

- Hawaii has the opportunity to provide national leadership in reducing oil dependence and greenhouse gas emissions.

- In 2005 Hawaii imported 42 million barrels (MMB) of crude oil and refined products and emitted 22 million tons (MMT) of greenhouse gases (GHG) – on a per capita basis this equates to 33 bbls of oil and 17.4T of GHG per capita. By 2030 under "business as usual", Hawaii's economic growth will drive oil imports up to 62 MMB and GHG emissions will rise to 31 MMT

- By 2030, Hawaii could reduce oil imports by 17 MMB and GHG emissions by 7.8 MMT (mid-range) and by 30 MMB of oil and 13.0 MMT GHG (high-range).

- All included GHG/crude oil demand abatement opportunities are economic at $60/bbl crude and $50/ton GHG. In 2030, taken together these measures would result in a ~5% savings in Hawaii's aggregate energy expense at $60bbl. The savings opportunity rises to ~27% at $120/bbl*

- If captured, these measures will allow Hawaii to derive between 28% (mid-range) and 48% (high-range) of its energy requirements from renewable sources*

- Economically, these reductions could occur in three phases
  1. Driving energy efficiency, developing geothermal/wind, and converting existing sugarcane into fuel
  2. Developing combined heat-AC-power, central station solar, firm-wind, and expanding ethanol
  3. Adopting next generation efficiency, distributed solar, wind-powered plug-in hybrids, and cellulosic biofuel

- Hawaii's natural endowments and economic structure make these opportunities more concentrated and less technology-dependent than elsewhere -- permitting, land-use, water, and infrastructure represent the biggest challenges

- In this context, Hawaii has the potential to move further and faster than the rest of the US, demonstrating the economic growth and job creation opportunity from reducing oil dependence and GHG emissions

* Excluding international aviation and marine

POTENTIAL ABATEMENT ROADMAP

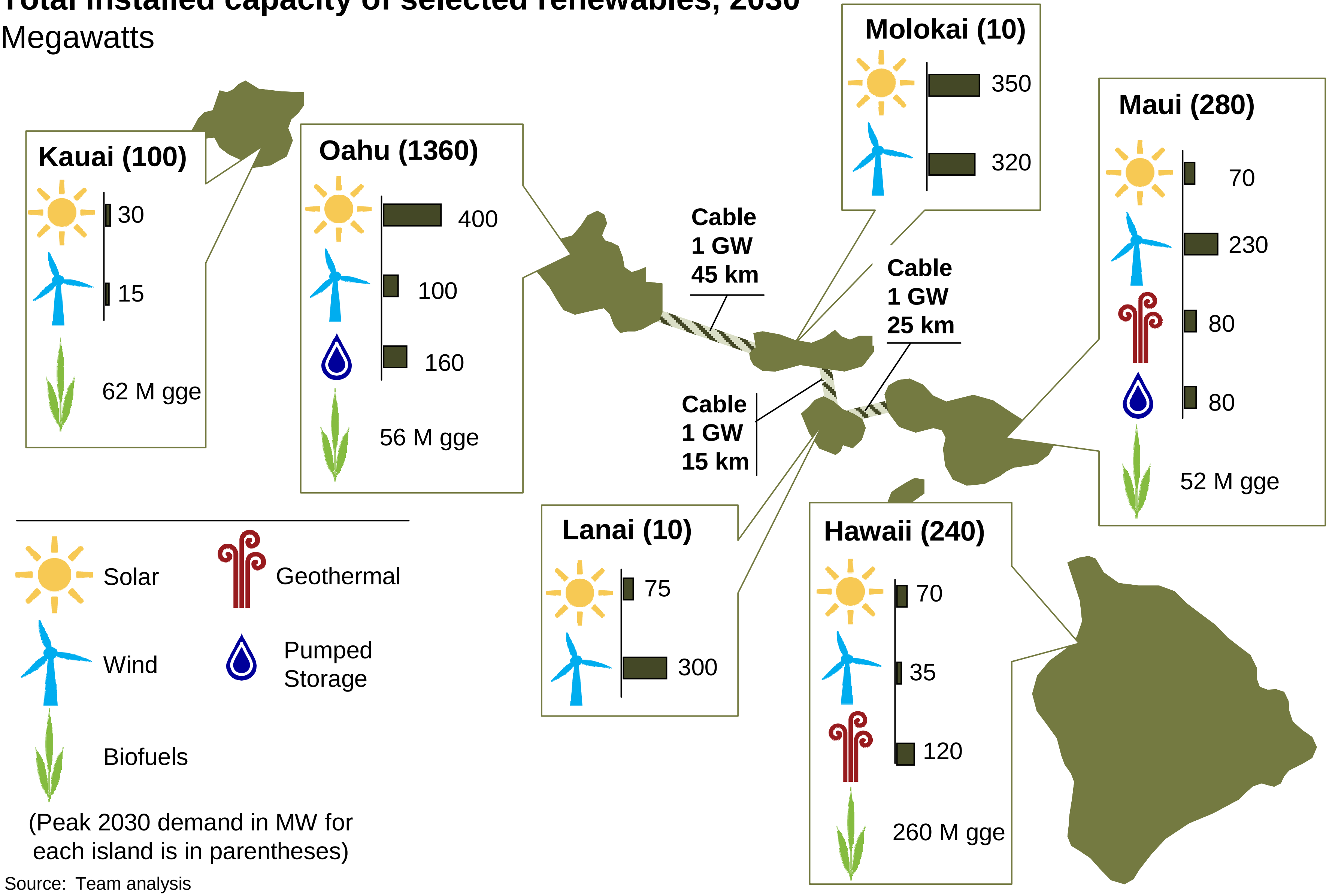
ILLUSTRATIVE

	Phase 1	Phase 2	Phase 3
Biofuels	**Ethanol 1st wave** • Convert existing sugarcane to ethanol production **Biomass 1st wave** • Build dedicated co-firing and bagasse plants	**Ethanol 2nd wave** • Expand ethanol production to 1969 sugarcane peak **Biomass 2nd wave** • Expand biomass capacity with ethanol production	**Ethanol 3rd wave** • Develop cellulosic production facilities on the Big Island **Biomass 3rd wave** • Build cellulosic firing plants
Renewable electricity	**Baseload geothermal** • Expand reliable geothermal production on the Big Island **Intermittent wind** • Deploy wind capacity on top of existing grid infrastructure	**Solar CSP** • Develop utility scale solar **Firm wind** • Connect Maui county and Oahu via cable • Develop pumped storage	**Wind and geo for PHEVs** • Deploy PHEV fleet and power with renewable resources **Distributed solar** • Encourage residential / commercial adoption of PV
Efficiency	**Efficient lighting** • Encourage adoption of high efficiency lighting (e.g., CFLs)	**Sea water AC and CHP** • Create distributed generation and cooling capacity	**Efficient electronics and LEDs** • Expand penetration of LEDs, efficient electronics
Incremental annual impact in 2030*	3.6 MMt CO2e 7.4 MMB oil	6.4 MMt CO2e 12.7 MMB	5.4 MMt CO2e 10.4 MMB

Source: Team analysis

IN HIGH CASE, SIGNIFICANT BUILDOUT OF RENEWABLES WILL OCCUR ON ALL ISLANDS

Total installed capacity of selected renewables, 2030
Megawatts



(Peak 2030 demand in MW for each island is in parentheses)

Source: Team analysis

Executive Summary

Business as usual

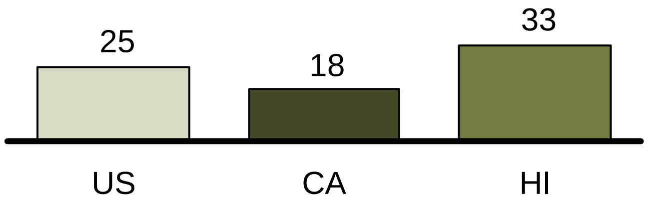
Greenhouse Gas Abatement

Oil Abatement

Appendix

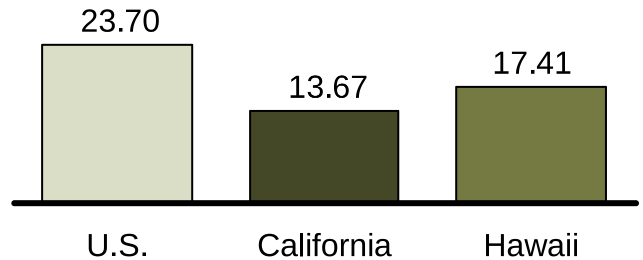
HAWAII IS MORE CO_2- EFFICIENT THAN THE U.S., BUT IS MORE OIL DEPENDENT

Per capita crude oil consumption*
Bbl / person / yr



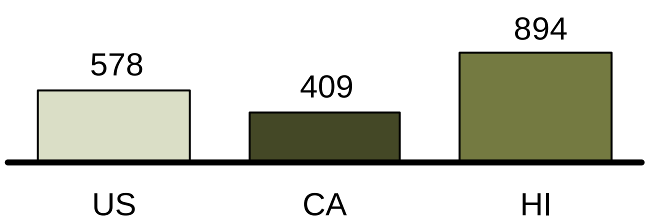
Oil consumption MMB / yr, 2005	7,524	650	42

Per capita greenhouse gas emissions*
t CO_2e / yr

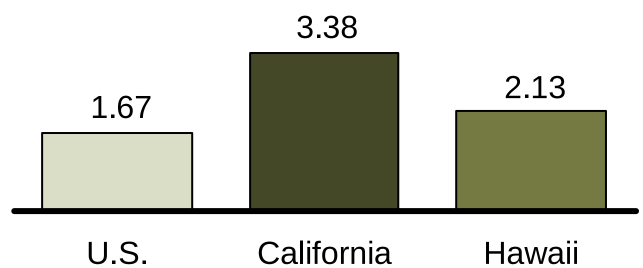


Total emissions Mt CO_2e / yr, 2005	7,006	487	22

Economic oil intensity*
Bbl / $Million GDP



Carbon productivity*
$1,000 GSP/ t$CO_2e$

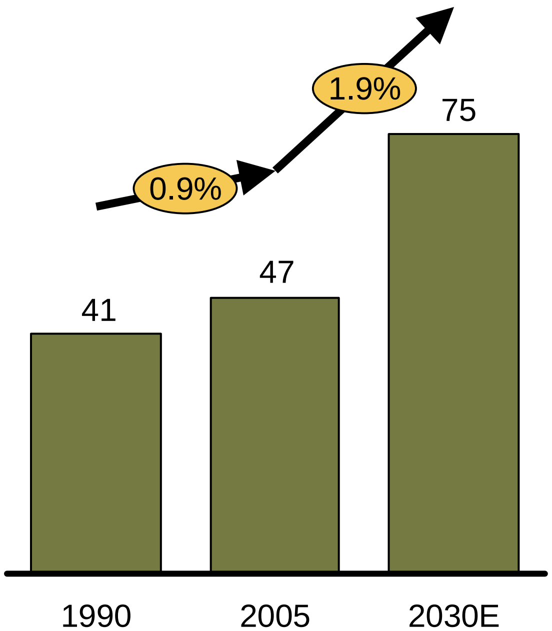


* Based on 2005 data; 2005 levels do not include international aviation and marine

Source: EIA, US DOT, Population Division, U.S. Census Bureau; EPA (sources of U.S. Greenhouse Gas Emissions and Sinks, 1990-2006); State of Hawaii Department of Business, Economic Development, and Tourism (DBEDT)

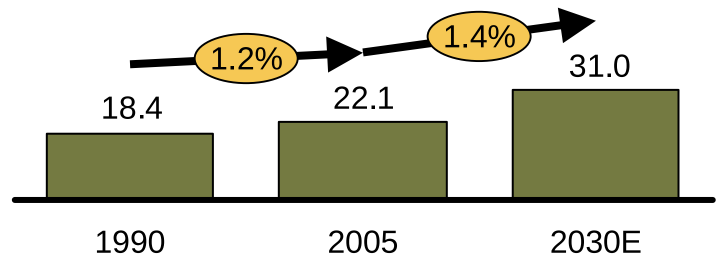
FUTURE ECONOMIC GROWTH WILL INCREASE BUSINESS AS USUAL GHG EMISSIONS AND CRUDE OIL IMPORTS

Hawaii state GDP
$ Billions/yr, CAGR %



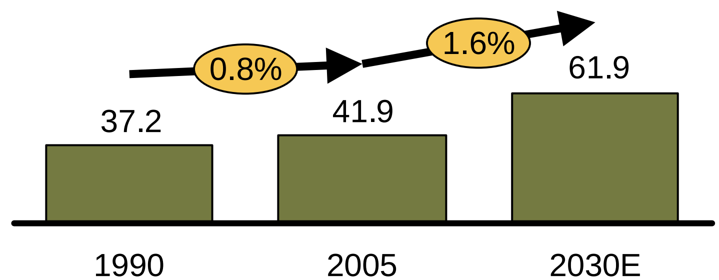
Increasing GDP results in
- Energy security concerns
- Greater environmental impact

BAU Hawaii state emissions*
Mt Co_2e/yr



	1990	2005	2030E
Carbon productivity ($/t$CO_2e$)	2,228	2,127**	2,419

BAU Hawaii crude oil imports*
MMB



	1990	2005	2030E
Oil productivity ($/bbl)	1,103	1,119	1,218

* Less international transport and cement manufacturing. BAU adjusted from RMI forecast

** Hawaii's CO_2e productivity decreased from 1990 to 2005 due to sluggish economic growth and shift toward coal power

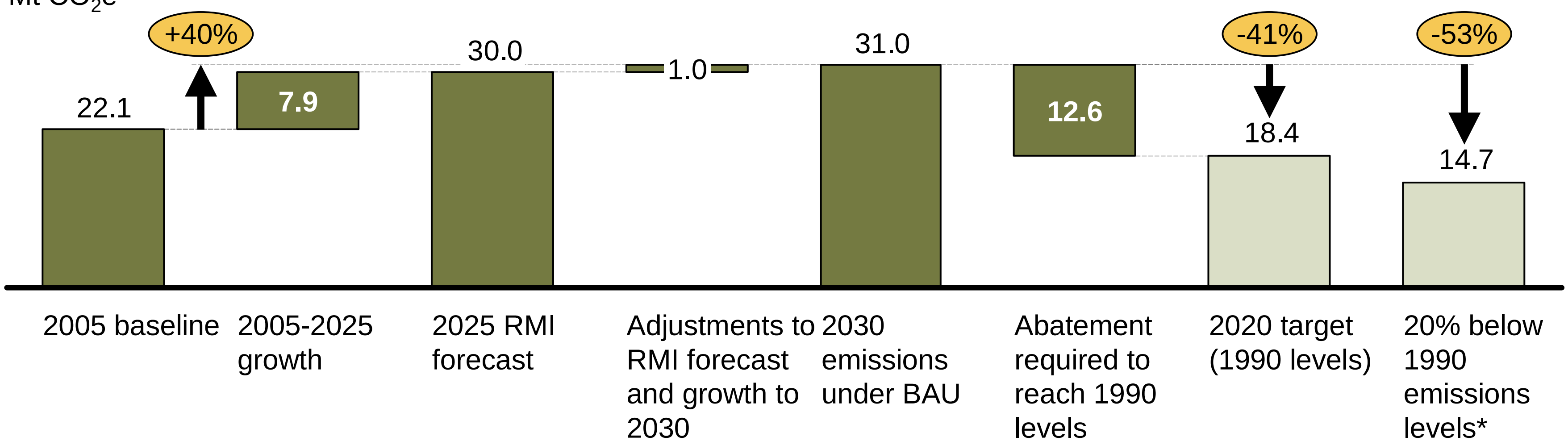
Source: Moody's; State of Hawaii DBEDT; RMI; team analysis

BASED ON FORECAST GROWTH, HAWAII FACES A SIGNIFICANT CHALLENGE TO MEET ENERGY AND EMISSIONS TARGETS

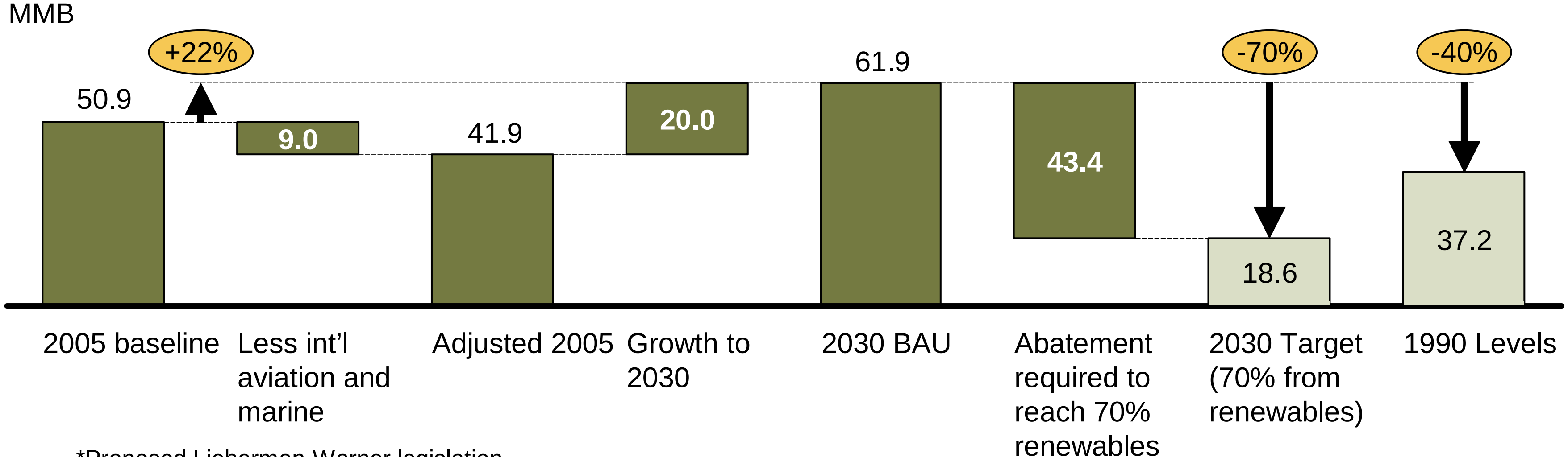
ESTIMATE

Target

GHG emissions forecast
Mt CO_2e



Oil demand forecast
MMB



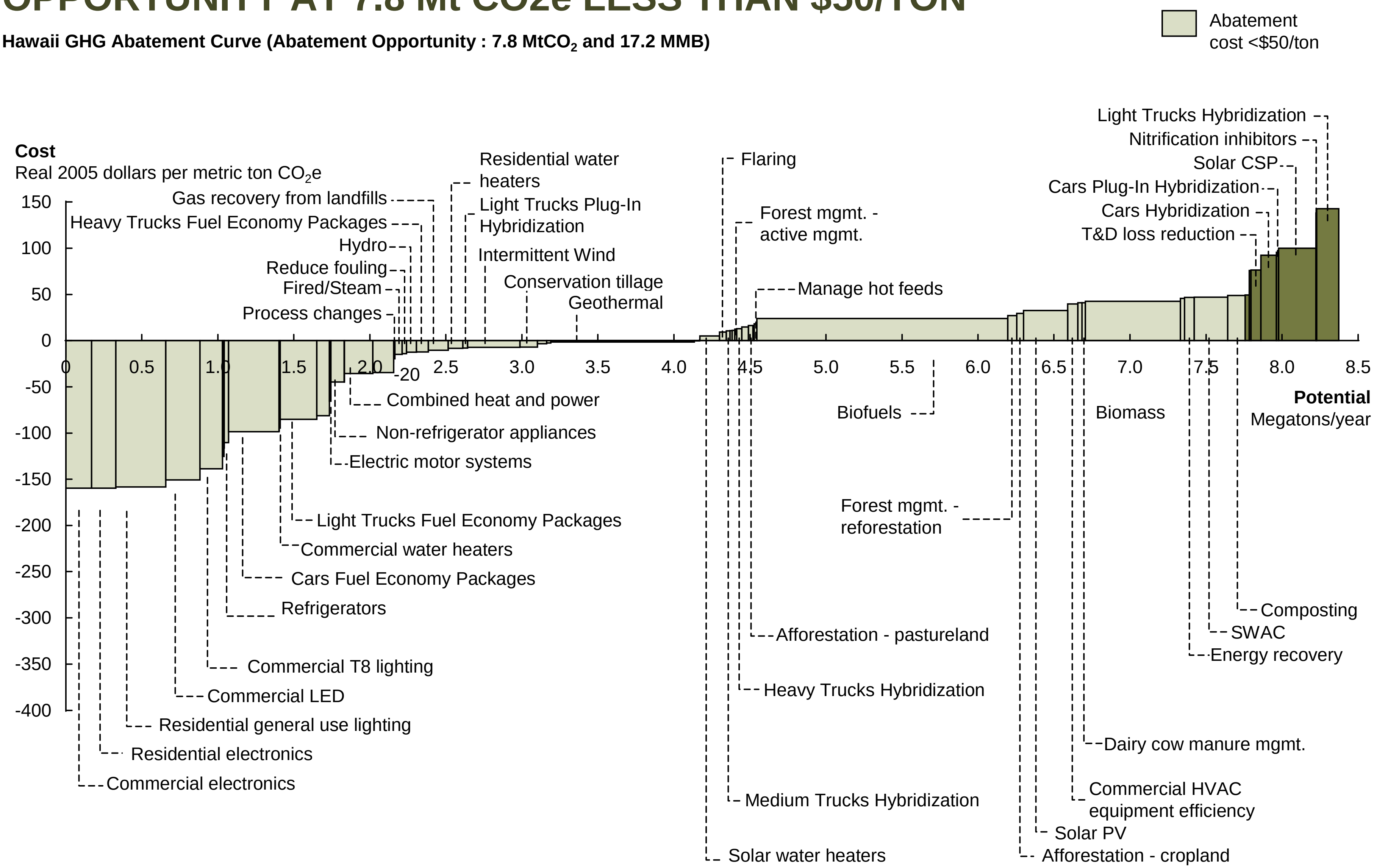
*Proposed Lieberman-Warner legislation

Source: State of Hawaii DBEDT; BEA Economics (2007); team analysis

WE ESTIMATE THE MID-RANGE GHG ABATEMENT OPPORTUNITY AT 7.8 Mt CO2e LESS THAN $50/TON

ANALYSIS BASED ON $60/BBL OIL

Hawaii GHG Abatement Curve (Abatement Opportunity : 7.8 MtCO_2 and 17.2 MMB)

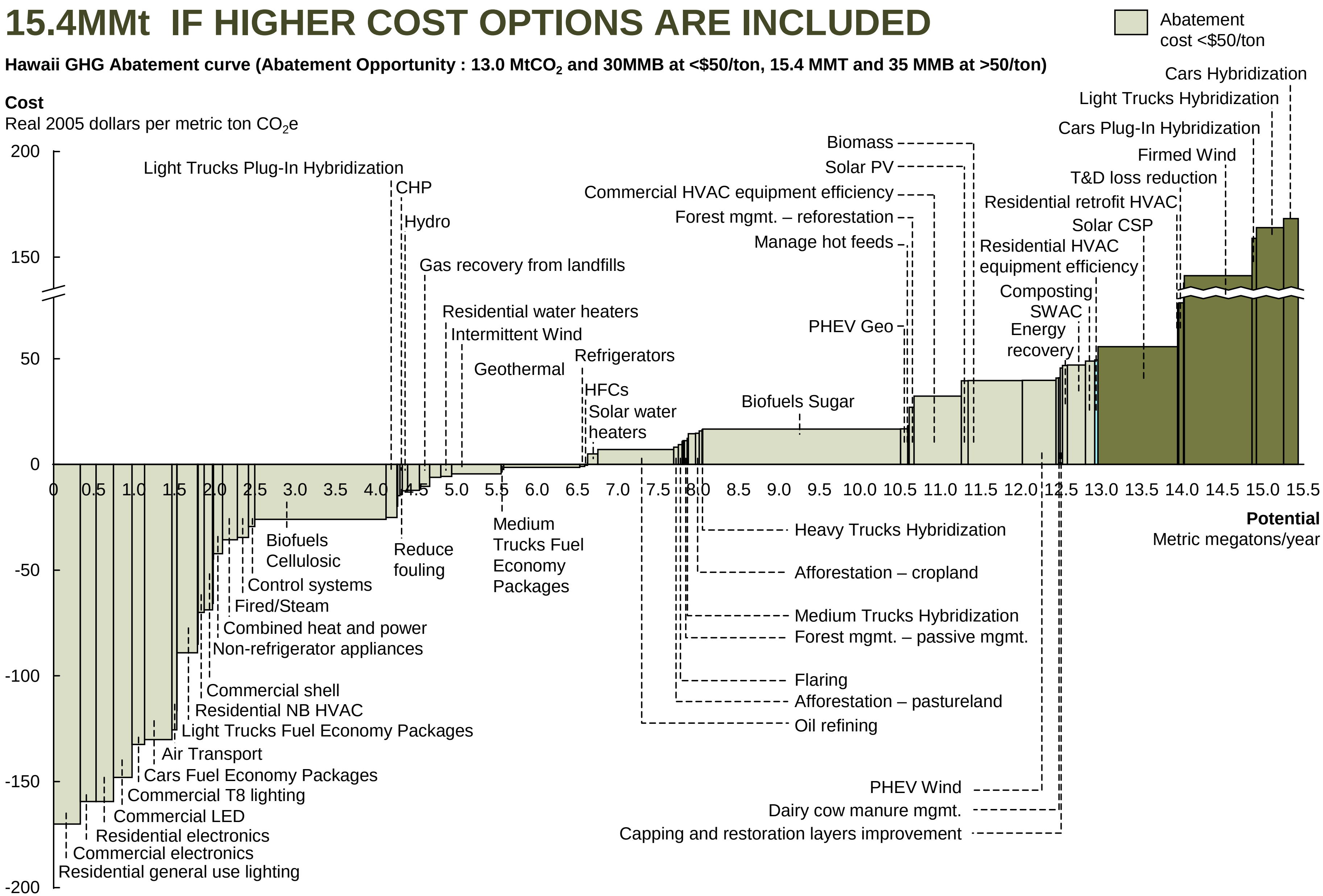


Source: Team analysis

HIGH CASE SHOWS 13.0MMt AT LESS THAN $50/TON AND 15.4MMt IF HIGHER COST OPTIONS ARE INCLUDED

ANALYSIS BASED ON $60/BBL OIL

Hawaii GHG Abatement curve (Abatement Opportunity : 13.0 $MtCO_2$ and 30MMB at <$50/ton, 15.4 MMT and 35 MMB at >50/ton)



Source: Team analysis

MEDIUM AND HIGH CASES DIFFER IN DEGREE OF COMMITMENT FROM SOCIETY

	Initiative	2005	Medium case*	High case*
Renewables	• Wind (intermittent / firm)	0 MW / 0 MW	140 MW / 0 MW	490 MW / 480 MW
	• Solar CSP	0 MW	170 MW	565 MW
	• Solar PV	1 MW	207 MW	420 MW
	• Geothermal	30 MW	140 MW	200 MW
	• Biomass	0 MW	105 MW	113 MW
	• Hydro	20 MW	43 MW	43 MW
	• Renewables for PHEVs	0 MW	0 MW	260 MW
Biofuels	• Sugarcane acreage	42,000 acres	242,000 acres	360,000 acres
	• Sugarcane ethanol	0 gge	193M gge	287M gge
	• Cellulosic acreage	0 acres	0 acres	135,000 acres (Big Island)
	• Cellulosic ethanol	0 gge	0 gge	170M gge
Light duty vehicles	• Cars**	23 mpg	34 mpg	42 mpg
	• Light trucks	16 mpg	24 mpg	29 mpg
	• HEVs/PHEVs/EVs	<1% / 0% / 0%	16% / 0% / 0%	26% / 16% / 0%
Commercial/ industrial	• Commercial CHP	1 MW	40 MW	40 MW
	• Refining abatement	0 Mbbl/day	0 Mbbl/day	80 Mbbl/day
Buildings energy efficiency	• Efficient lighting	8%	70%	75%
	• Central AC	SEER 10	SEER 15	SEER 18
Mt CO_2e abated			**7.8**	**13.0**

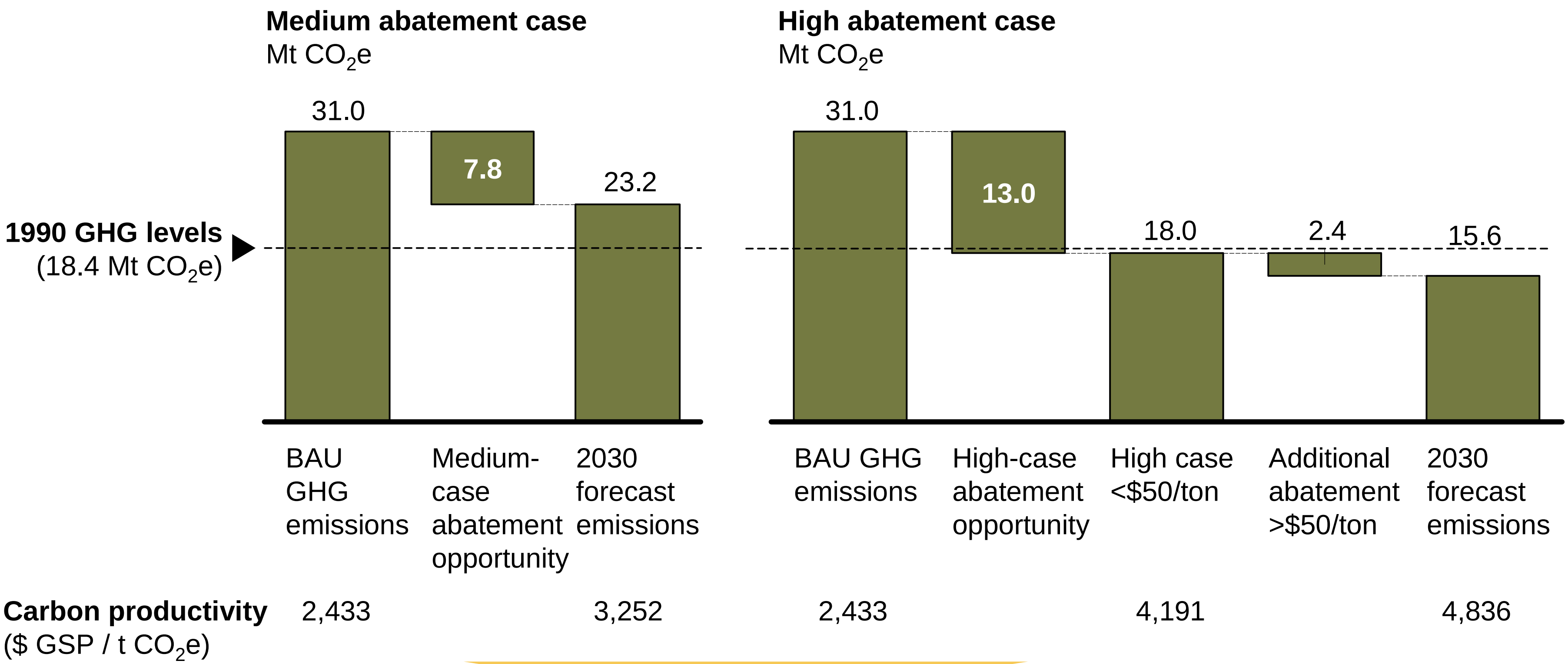
* Includes abatement opportunities above $50/ton

** Average for 2030 fleet; average across gasoline internal combustion, diesel, hybrid electric, and plug-in hybrid electric vehicles;

Source: Team analysis

WITH AGGRESSIVE ACTION, HAWAII CAN LIMIT GHG EMISSIONS TO 1990 LEVELS IN 2030

ASSESSMENT OF $60/BBL ABATEMENT CASE



- The medium abatement case falls 4.8Mt short of 1990 levels
- The high abatement case uses high penetrations of renewables and energy efficiency measures, but Hawaii remains slightly short of 1990 emissions levels
- If higher cost options (>$50/ton) were included, Hawaii would be well below 1990 GHG levels

Source: Team analysis

Executive Summary

Business as usual

Greenhouse gas abatement

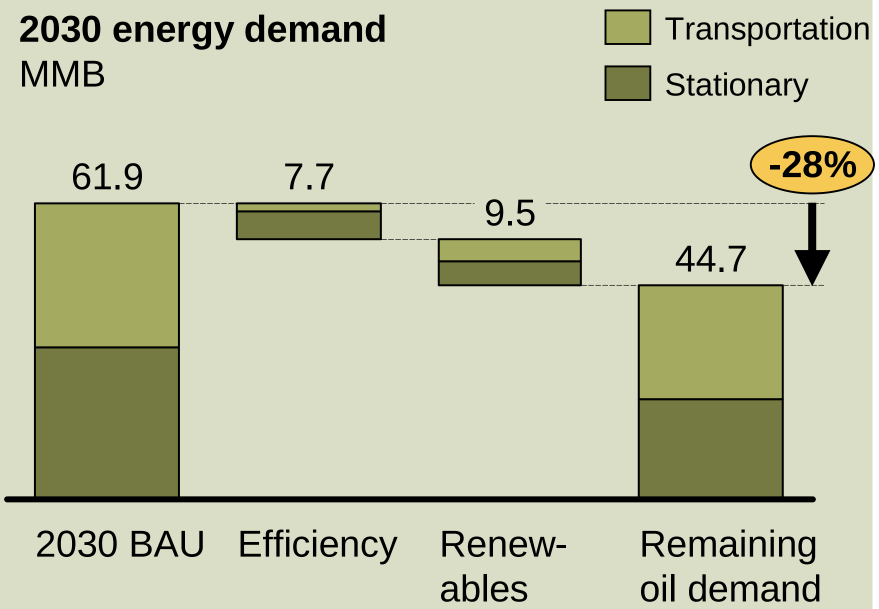
Oil abatement

Appendix

GHG ABATEMENT ACTIONS ALSO RESULT IN A SUBSTANTIAL REDUCTION IN CRUDE OIL IMPORTS

Medium Case

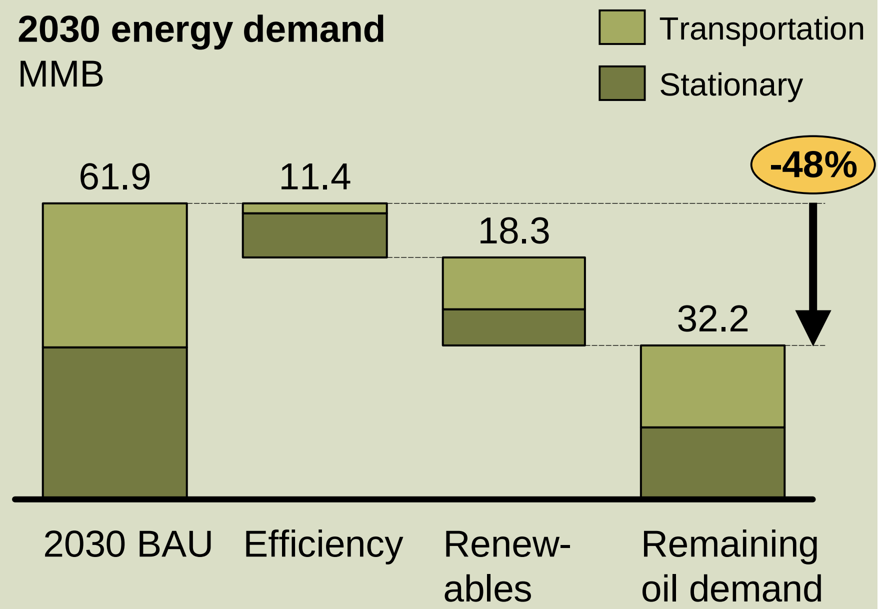
2030 energy demand
MMB



- 15% of total oil demand economically displaced by renewables
- 12% of total oil demand economically abated from efficiency measures

High Case

2030 energy demand
MMB

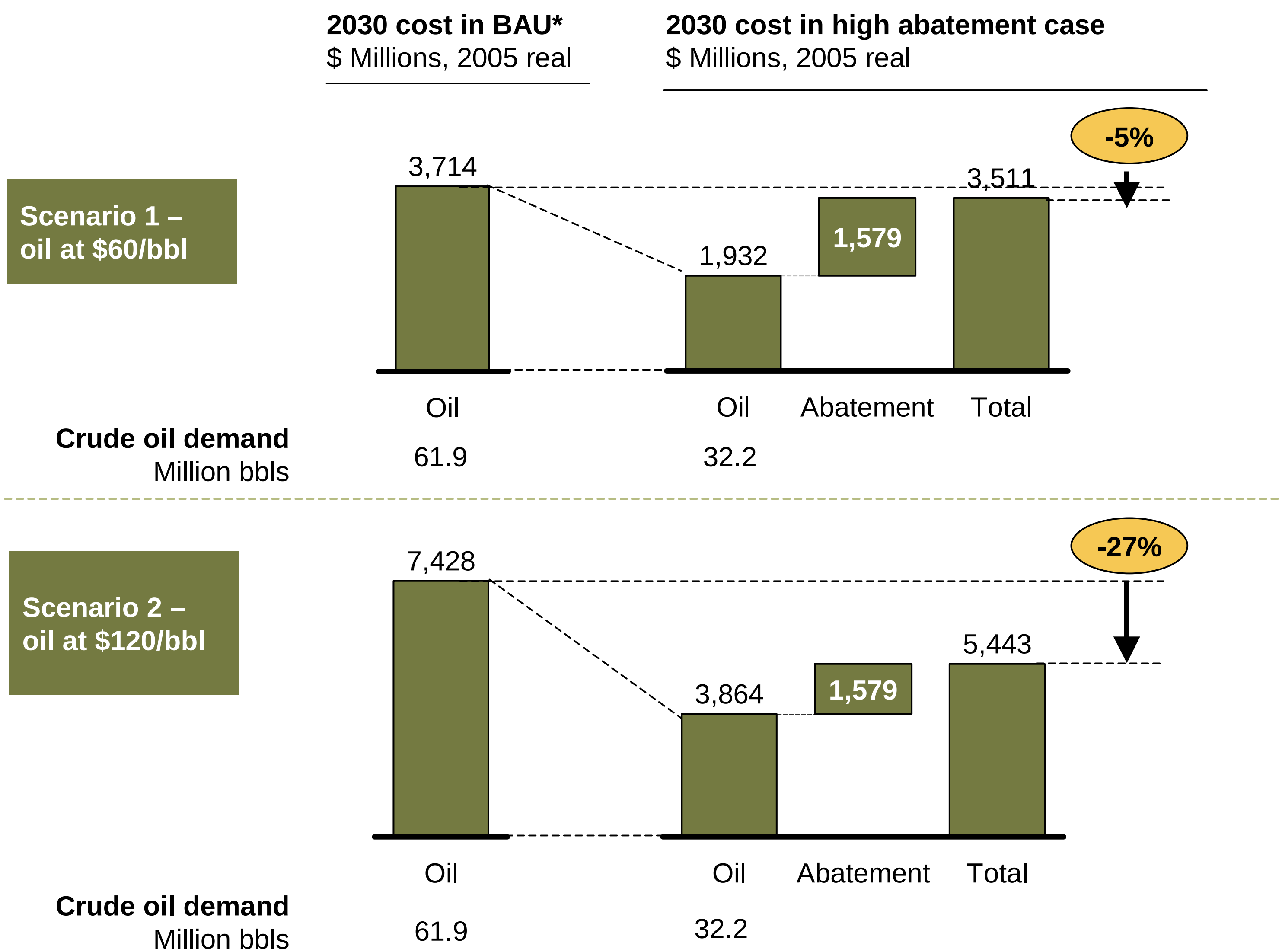


- 30% of total energy economically provided by renewables
- 18% of total oil demand economically abated from efficiency measures

Source: Team analysis; EIA; DBEDT

ECONOMICAL ABATEMENT INITIATIVES COULD REDUCE ENERGY SPEND BY 5-27% IN 2030

BASED ON HIGH GHG ABATEMENT CASE

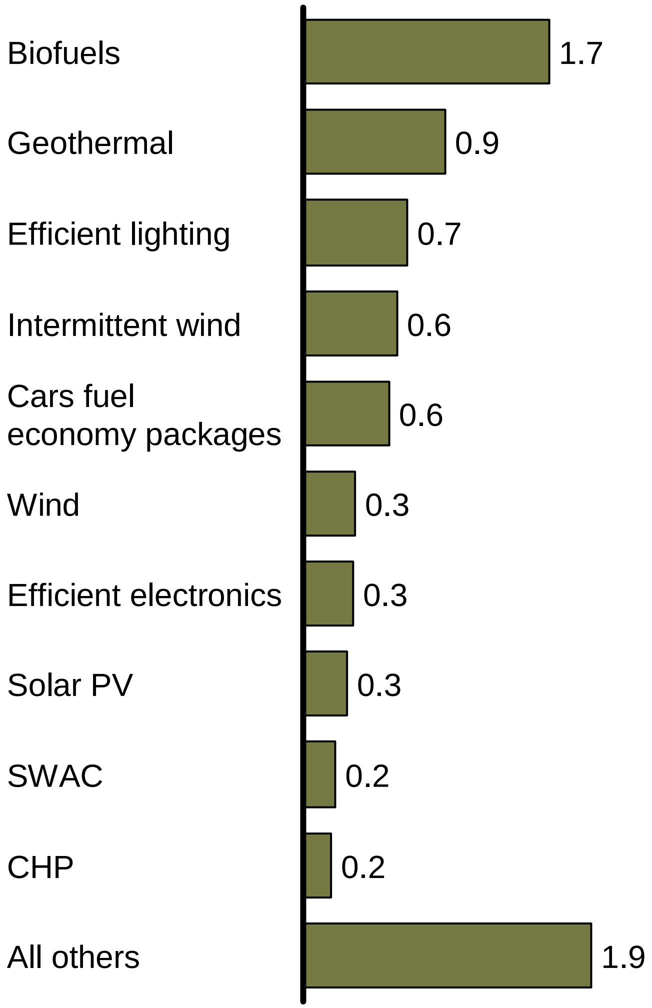


* BAU does not include cost of coal

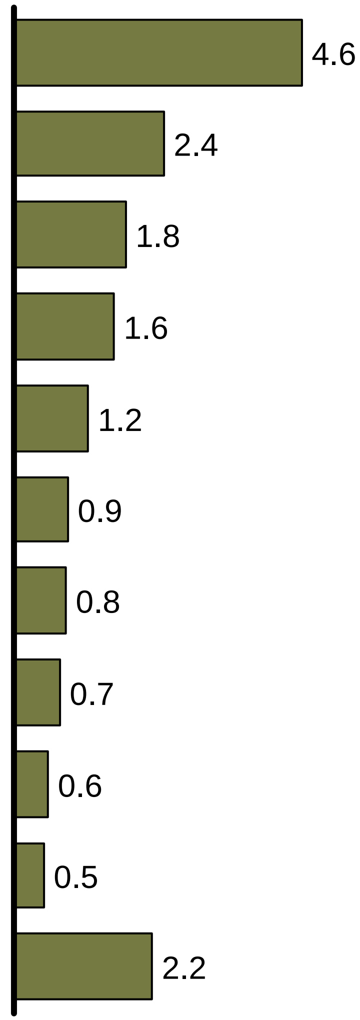
Source: Team analysis

75% OF GHG ABATEMENT POTENTIAL (AND NEARLY 90% OF OIL ABATEMENT) CAN BE ACHIEVED FROM TOP TEN INITIATIVES

Top 10 GHG Abatement Initiatives for Hawaii
MMt CO2e



Oil abatement
MMB



- Top 10 initiatives account for 5.9 MMt abatement and 15.0 MMB
- Hawaii has benefit of being able to focus on fewer, higher-impact initiatives than the U.S.
- Ensuring progress against these initiatives is critical to capturing full abatement potential

Source: Team analysis

CONCLUSIONS

Hawaii has the potential to move further and faster than the rest of the US, providing national leadership to demonstrate the opportunities in reducing oil dependence and GHG emissions

- Energy efficiency opportunities represent the most economically attractive initiatives – an expedited package of policy and economic action to ensure adoption will pay dividends
- Hawaii is blessed with broad, economic, renewable energy potential--developing the local ethanol, geothermal, solar, and wind resources relatively quickly will provide a solid foundation
- Both energy efficiency and renewables depend on upgrading the island's power transmission and distribution infrastructure
- Longer-term there are opportunities to take a leadership role in renewable powered electric/hybrid vehicles and cellulosic biofuels as well as to lead research efforts on algae-based biofuels, ocean thermal, wave technology, and other opportunities unique to Hawaii
- All of these opportunities will require a clear, consistent policy framework for measuring, monitoring, and exchanging the benefits from these investments as well as the siting, permitting, and interconnection regulatory approval processes to make these opportunities financeable
- At a minimum, these initiatives should provide relatively low cost insurance against the risk of major oil price spikes, but more broadly, these should provide a platform for economic growth and job creation – early action provides the opportunity for differentiation

APPENDIX

Methodology

BAU assumptions

Additional analysis

Sector-by-sector assumptions

DOE AND THE STATE OF HAWAII SEEK A CONSISTENT VIEW OF OIL REDUCTION AND GREENHOUSE GAS ABATEMENT OPPORTUNITIES

Context

- DoE and the State of Hawaii have launched the Hawaii Clean Energy Initiative to determine the feasibility of reaching 70% of Hawaii's energy needs from renewable sources
  - GHG abatement
  - Energy security
- McKinsey has developed a rigorous methodology to estimate the volume and cost of GHG abatement opportunities and applied it at multiple levels
  - Global
  - U.S. (and other countries)
  - U.S. states
- As a "closed system" with apparently abundant renewable energy resources, Hawaii is ideal to test the limits of what's possible in GHG abatement and renewable energy usage

Objectives

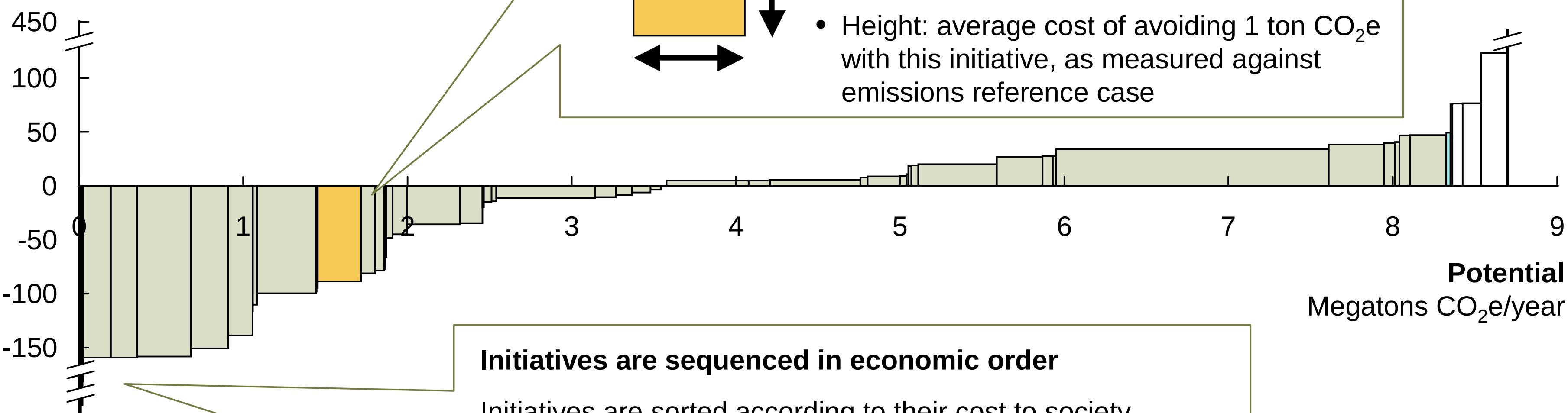
- Develop an inventory of quantified (volume, cost/ton) GHG abatement opportunities for the State of Hawaii
  - Scale U.S.-wide opportunities to Hawaii based on appropriate metrics (e.g., GDP, vehicle miles traveled, AC penetration, etc.)
  - Develop Hawaii-specific analyses on unique abatement opportunities (e.g., sea water air conditioning, sugar cane, geothermal, etc.)
- Assess GHG abatement opportunities' impact on total crude oil imports

Deliverables

- Hawaii greenhouse gas cost curve based on the U.S. methodology
- Medium and high abatement cases based on the level of commitment from society (e.g., willingness to convert existing cropland to biofuel production)
- Description of implications of GHG abatement options on oil demand in Hawaii

A COST CURVE ILLUSTRATES THE RELATIVE ECONOMICS AND IMPACT OF ABATEMENT OPPORTUNITIES

Cost
Real 2005 dollars per metric ton CO_2e



Potential
Megatons CO_2e/year

How to read an abatement cost curve

Each bar is an abatement initiative

Each bar represents one initiative or a group of closely related initiatives (e.g., residential general use lighting)

- Width: amount of CO_2e that can be reduced annually by this initiative
- Height: average cost of avoiding 1 ton CO_2e with this initiative, as measured against emissions reference case

Initiatives are sequenced in economic order

Initiatives are sorted according to their cost to society

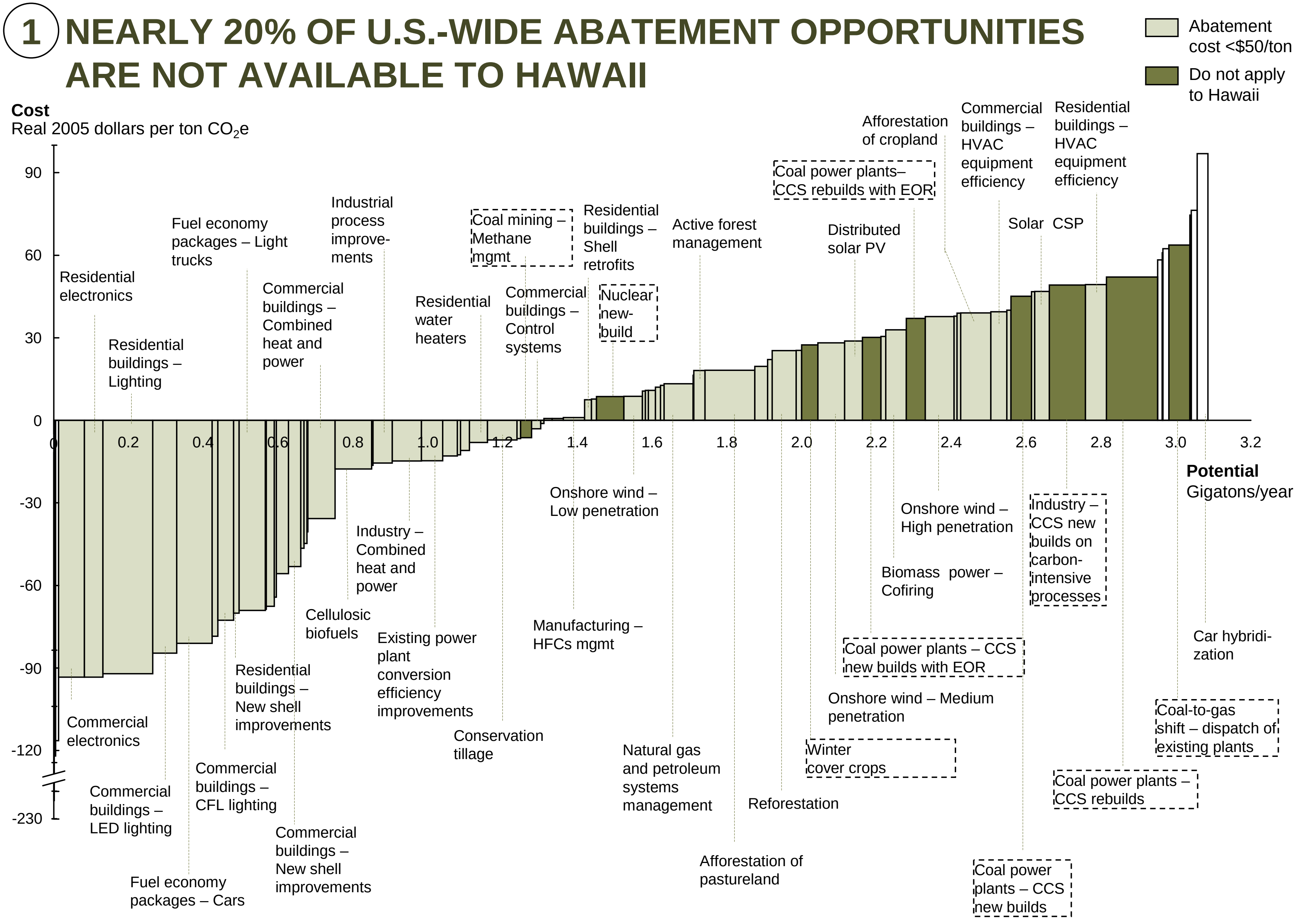
- "Negative cost" (below the horizontal axis) indicates a net benefit or savings to society over the lifecycle of the initiative; "positive cost" (above the axis) means that capturing the abatement would result in incremental lifecycle costs vs. the reference case
- Capturing "negative cost" initiatives are often hindered by nonmarket forces (e.g., NIMBY-ism, principal-agent issues, etc.)

WE HAVE SIZED ABATEMENT OPPORTUNITIES IN HAWAII

METHODOLOGY

	Approach	Example opportunities	Description
1 **Not applicable to Hawaii**	• Do not include	• Nuclear	• State law prohibits nuclear facilities, not enough scale for nuclear
		• Coal mining	• No coal mines on islands
		• Offshore wind	• Sea floor too deep for offshore wind
		• CCS	• No CCS reservoirs available, undersea CCS not proven
2 **Scaled from U.S. curve**	• Scale based on HI usage factors (e.g., population)	• Cars fuel economy packages	• Scaled based on vehicle miles traveled (assumes comparable fleet profiles)
		• Residential electronics	• Scaled based on number of households (assumes comparable penetration and type of consumer electronics)
		• Residential lighting	• Scaled based on number of households (assumes comparable penetration of CFLs and LEDs)
3 **Unique to Hawaii**	• Develop Hawaii-specific approach	• Biofuels	• Modeled production of sugar ethanol based on acreage and productivity studies
		• CHP	• Used detailed estimates of commercial CHP opportunity
		• HVAC efficiency	• Lower AC penetration requires different approach than U.S. curve
		• Sea water air conditioning	• Have firm-cost estimates from existing projects. Not included in U.S. curve
		• Oil refining	• Reducing demand for oil through efficiency and renewables may reduce need for refining capacity
		• PHEVs	• Fleet dynamics (e.g., rental cars) make it more likely that PHEVs can achieve high penetration rates

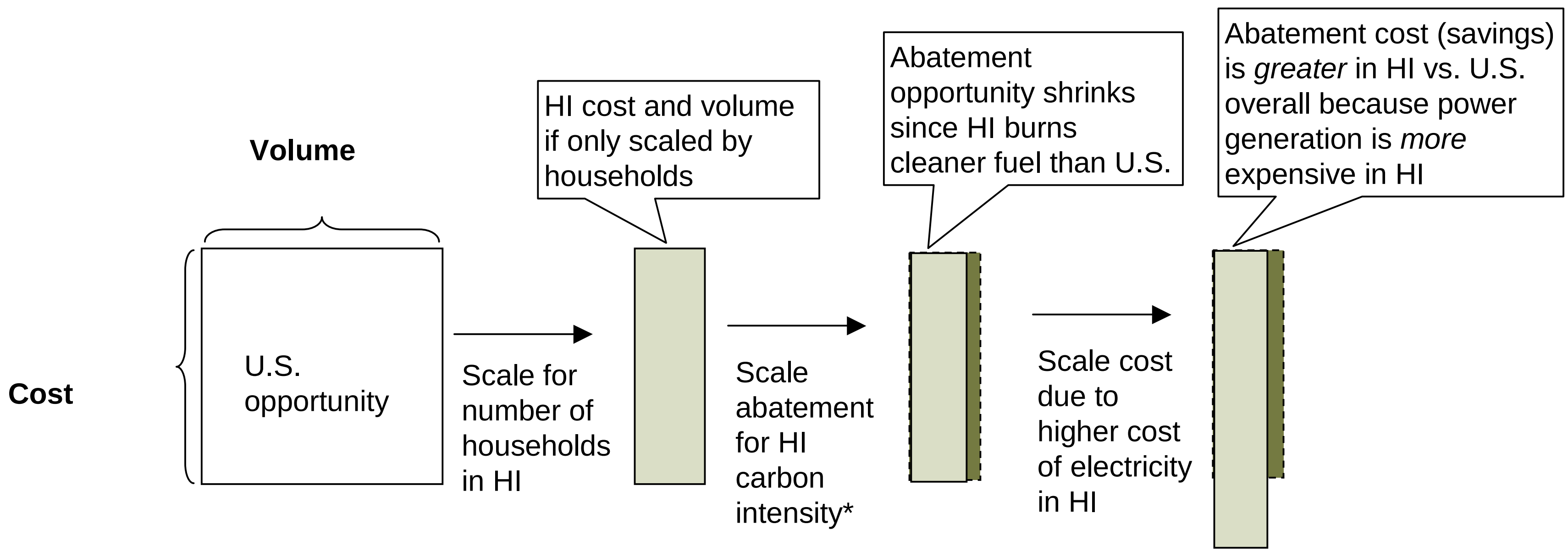
1 NEARLY 20% OF U.S.-WIDE ABATEMENT OPPORTUNITIES ARE NOT AVAILABLE TO HAWAII



Source: McKinsey analysis

② WE HAVE ASSESSED HAWAII ABATEMENT OPPORTUNITIES BY SCALING THE U.S. ABATEMENT CURVE, OPPORTUNITY-BY-OPPORTUNITY

Example: Residential electronics abatement opportunity (medium penetration)



Cost ($/ton abated)	(93.28)	(93.28)	(93.28)	(159.42)
Volume megaton CO_2e	49.53	0.173	0.166	0.166

* HI uses mostly fuel oil for power generation – slightly lower carbon intensity than in rest of U.S. (dominated by coal)

Source: Team analysis

OVERVIEW OF US AND HAWAII GHG ABATEMENT MODEL

Our model:

- Builds on government business as usual forecast, proprietary McKinsey expertise as well as knowledge and expertise of sponsors of the effort
- Provides an understanding of the relative magnitude and cost of greenhouse gas abatement opportunities to society across sectors and timeframes
- Evaluates abatement costs and potential relative to the "business-as-usual" case from the DBEDT Hawaii Greenhouse Gas Emissions Inventory and other government reports
- Evaluates the supply potential of available abatement opportunities
- Considers dynamic interactions within sectors and important cross-sectoral linkages, avoiding double-counting of abatement opportunities

Our model does not:

- Estimate today's cost of abatement options
- Forecast the "price" of CO2 – costs inherent to the cost curve do not translate directly to carbon taxes required to accomplish specific public policy objectives or carbon price that may emerge through the cap-and-trade system
- Evaluate the sequence in which abatement should be accomplished – no attempt to identify the optimal sequence of abatement undertaken
- Function as a general equilibrium macroeconomic model with respect to commodity price movements
- Simulate every cross-sectoral dynamic interaction

Source: Team analysis

CRITERIA FOR SCREENING ABATEMENT OPPORTUNITIES BASED ON TECHNOLOGICAL MATURITY

Criteria

- Technology is at least in the pilot stage
- Widely shared point of view among professionals on technical and commercial viability in the medium-term (10-15 years)
- Well-understood technological and economical challenges that can be dimensionalized
- Compelling forces at work supporting technology (e.g. policy and / or industry support, tangible benefits such as energy security, expected attractive economics)

Examples of excluded technologies

- Biodiesel from algae
- Biokerosene
- CCS with Enhanced Gas Recovery
- Biomass gasification in power generation
- Electric vehicles (Plug-in Hybrid EVs are included)
- OTEC

Source: Team analysis

KEY ASSUMPTIONS FOR THE MCKINSEY GLOBAL, US, AND HAWAII GHG ABATEMENT MODELS

	Approach	Rationale
Abatement costs	• Understand factors contributing to cost and attempt to eliminate margins, particularly those due to near-term market conditions – As much as possible we remove pricing distortions to create an internally consistent cost structure, however some residual margins can remain	• Focusing on costs allows for direct comparisons of different options • To develop a long-term perspective it is necessary to eliminate price run-ups, as high margins are not maintainable in the long run • Profit is not a cost to society, but a transfer of wealth
Capital costs	• Use a 7% cost of capital for calculating the levelized cost of capital	• Abatement of carbon dioxide is a social imperative and thus the cost of capital should be set to a minimum level
Taxes, incentives, tariffs, etc.	• Do not consider in calculations	• These represent transfers of wealth • They are difficult to project • They are set via policy and do not represent costs associated with a particular technology

Translating curve to individual actors' perspectives requires adjustments to several factors including, cost of capital, profit margins and current and future costs

Source: US GHG Abatement Cost Curve team

COSTS OF RENEWABLES VARY IN MEDIUM AND HIGH CASES

Challenge	Challenges to increasing penetration of renewables…	…lead to different cost regimes
Appropriate sites	• On most islands, there are limited sites where high-quality resources are available and are close to existing transmission infrastructure	• Expanding renewables footprint requires development of higher cost sites (i.e., those with lower solar insulation or less constant wind profiles)
Firming	• Adding large intermittent capacity to grid creates challenges in matching generation to demand	• Pumped storage, molten salt, and passive PHEVs provide ability to convert "as-available" resources into "on-demand" resources, but add significant costs • Internal combustion backup and fast cycling/peaking burns more fossil fuels
Inter-island connections	• To fully develop renewable resources on neighboring islands, cables must be deployed to connect supply to demand on Oahu and Maui	• Cost of laying cable, terminal stations and additional transmission capability must be assigned to resources developed on Lanai and Molokai
Infrastructure investment	• Expanding distributed generation capacity (Solar PV) and use of intermittent resources will require smart grid/net metering capabilities	• Distribution costs will increase to pay for infrastructure upgrades
Learning and adoption curves	• Many technologies (especially solar CSP & PV) depend on a steep learning curve to reduce costs, which will be driven by forces *outside* Hawaii	• Estimates of cost reductions are based on anticipated adoption of technologies in the United States

Source: Team analysis

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Methodology

BAU assumptions

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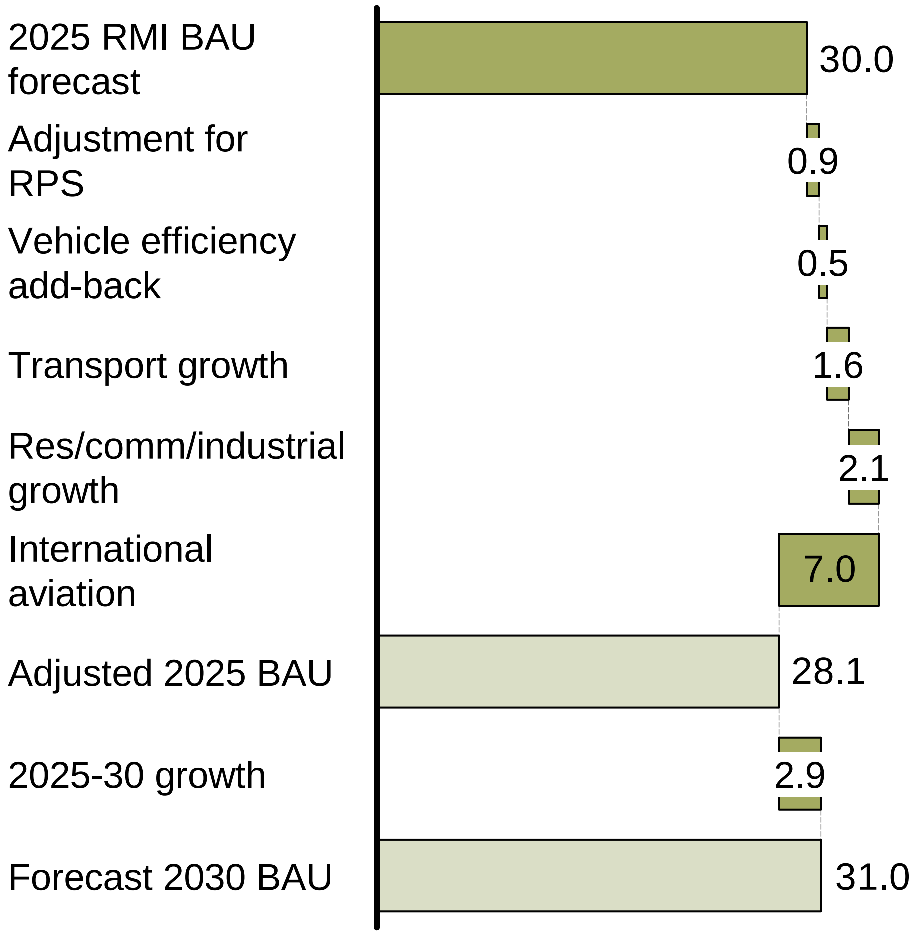
Sector-by-sector assumptions

WE MODIFIED THE RMI BUSINESS-AS-USUAL FORECAST

PRELIMINARY

Comparison of business-as-usual (BAU) forecasts
Mt CO_2e

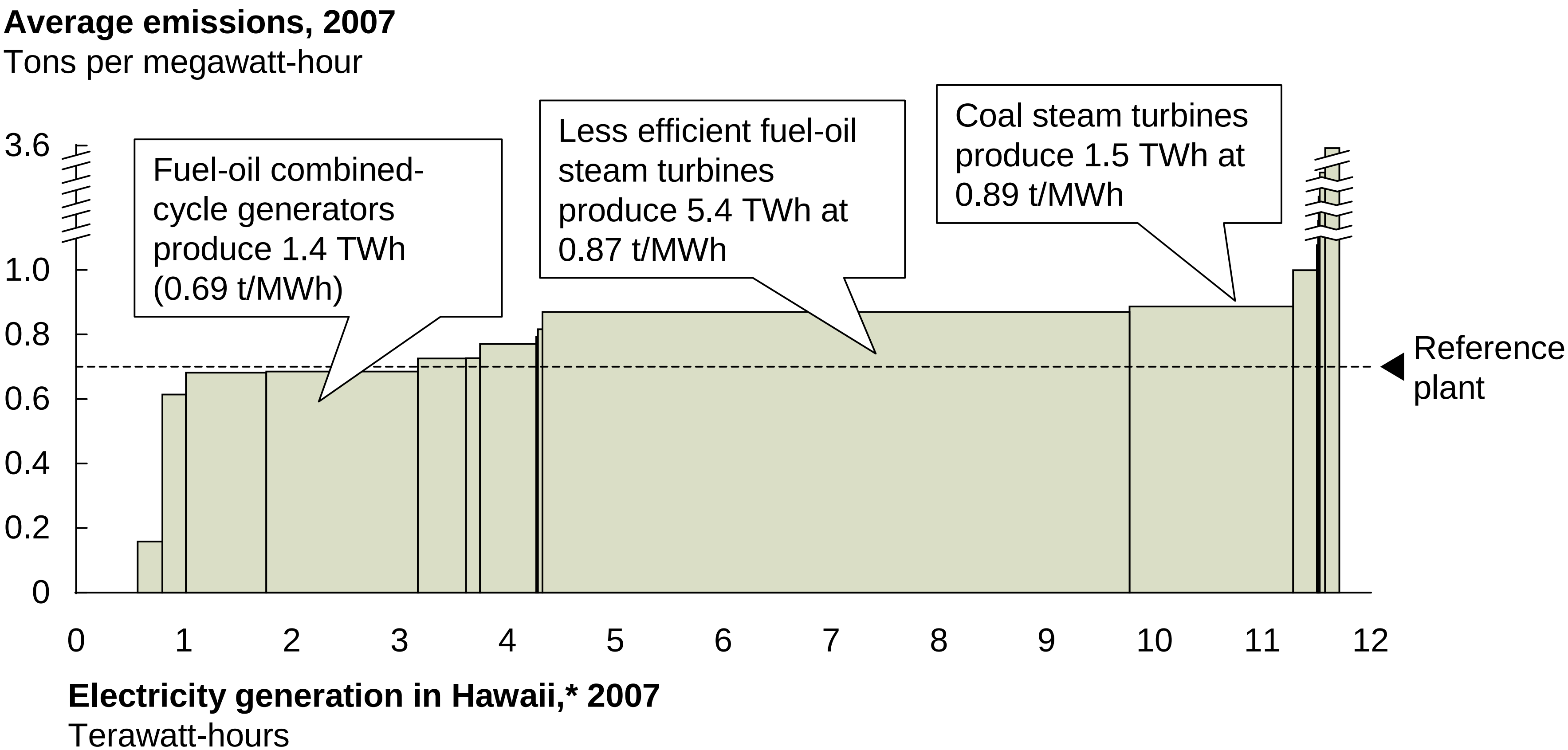


Description

- Baseline BAU from IRP
- RMI emissions estimates include anticipated reductions from reaching 20% renewables
- Forecast assumed 11% efficiency increase in transportation fleet
- Forecast assumes reduction in demand, adjusted to reflect U.S. efficiency
- Scaled to reflect GDP growth
- Less international transport, scaled for GDP growth
- Scaled to reflect GDP growth

Source: Policy Recommendations for Hawaii's Energy Future 2007, BEA; State of Hawaii DBEDT

REFERENCE PLANT DETERMINES EMISSIONS OF EACH MARGINAL MWH ABATED

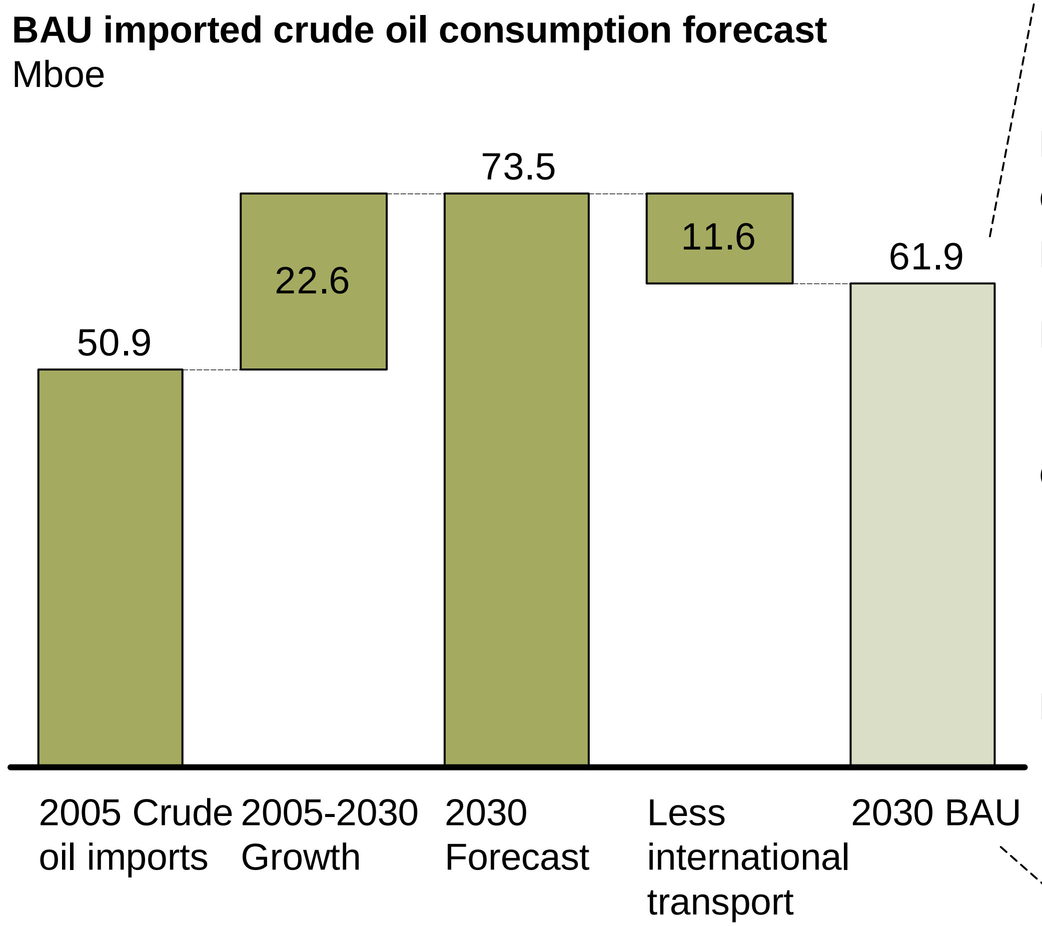


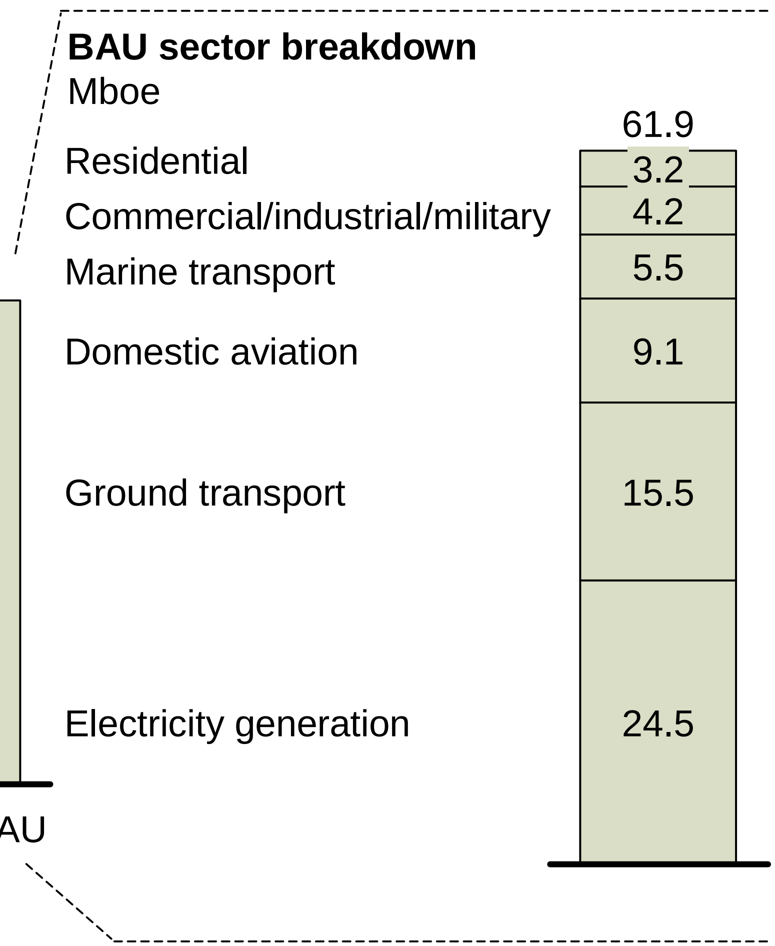
- We have assumed that incremental peak load would be provided by a combined-cycle fuel oil generator
- Does not include renewables or coal as part of dispatchable peak load

* Includes all Islands

Source: Energy Velocity, EIA; team analysis

BASED ON RMI FORECASTS, WE DEVELOPED A BAU FOR OIL

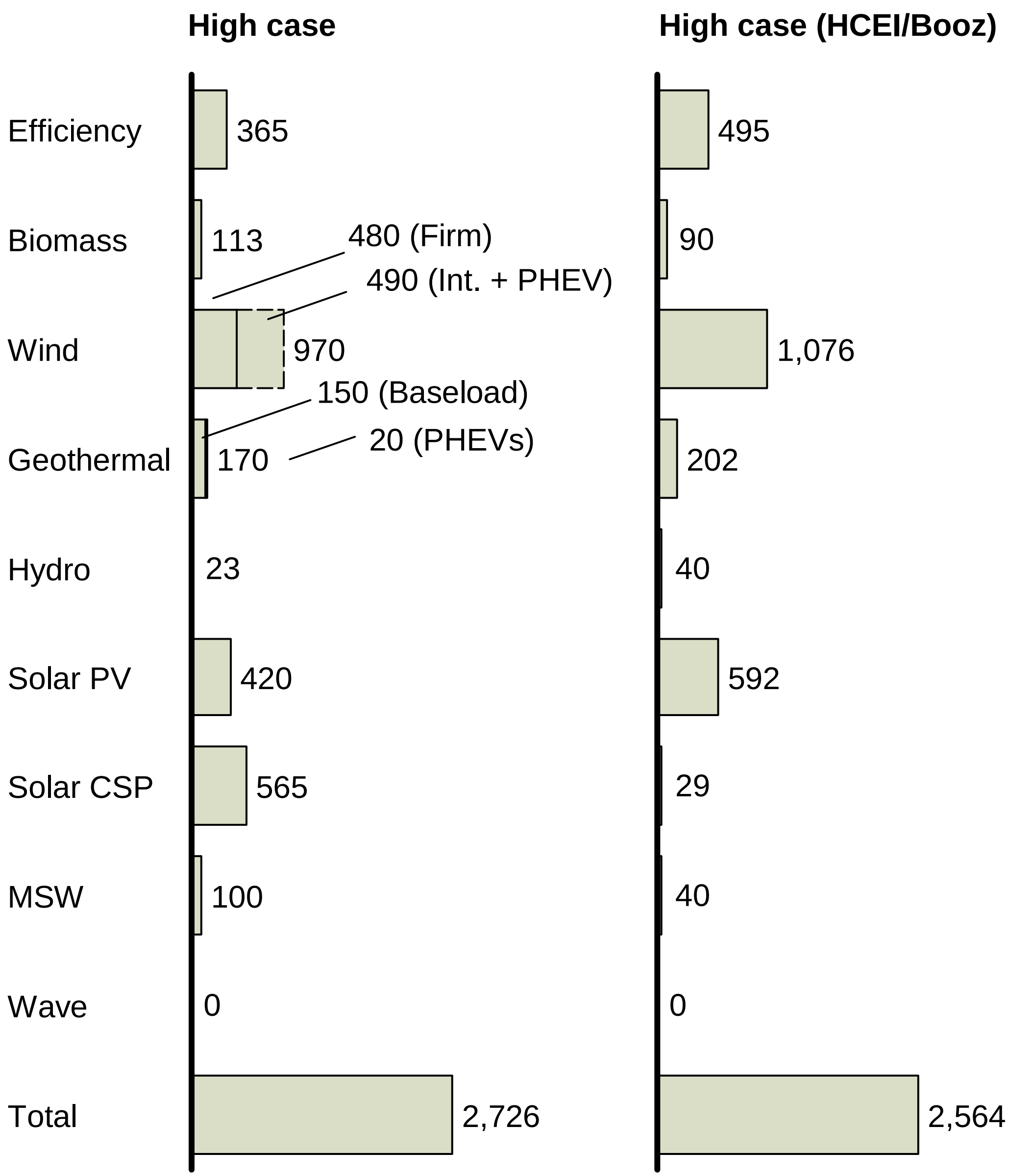




Source: Hawaii's Energy Future; RMI 2007

COMPARISON OF ELECTRICITY SCENARIOS

MW of capacity



Comments / source

- HCEI assumes large % of net zero energy buildings.
- Estimates include firing bagasse from increased biofuels
- Both scenarios assumes cable connecting Oahu and Maui/Molokai
- Assumes Maui exports geothermal to Oahu via cable
- HCEI assumes 2kW system on 50% of res., 100kW on 50% of comm.
- HCEI only includes CSP on Kauai
- Bollmeier
- Not included in HCEI, minimal existing cost data . RMI estimated based on “personal communication”

Source: HCEI, Booz Allen Hamilton, RMI

APPENDIX

Methodology

BAU assumptions

Additional analysis

Sector-by-sector assumptions

HAWAII HAS TAKEN A NUMBER OF STEPS TO PROMOTE ENERGY INDEPENDENCE AND REDUCE ITS ENVIRONMENTAL IMPACT

Alternative Fuel Standard (Act 240)

Goal of providing 10% of highway fuel demand from alternative fuels by 2010; 15% by 2015; and 20% by 2020

Hawaii Renewable Portfolio Standard (Act 95)

Requires that utilities purchase or generate 10% of their net electricity sales from renewable sources by 2010; 15% by 2015; and 20% by 2020

Hawaii Clean Energy Initiative

Memorandum of Understanding between State of Hawaii and U.S. Department of Energy to drive adoption of renewable energy in the state, with a goal of reaching 70% of energy from renewables

Greenhouse Gas Emissions to 1990 Levels (Act 234)

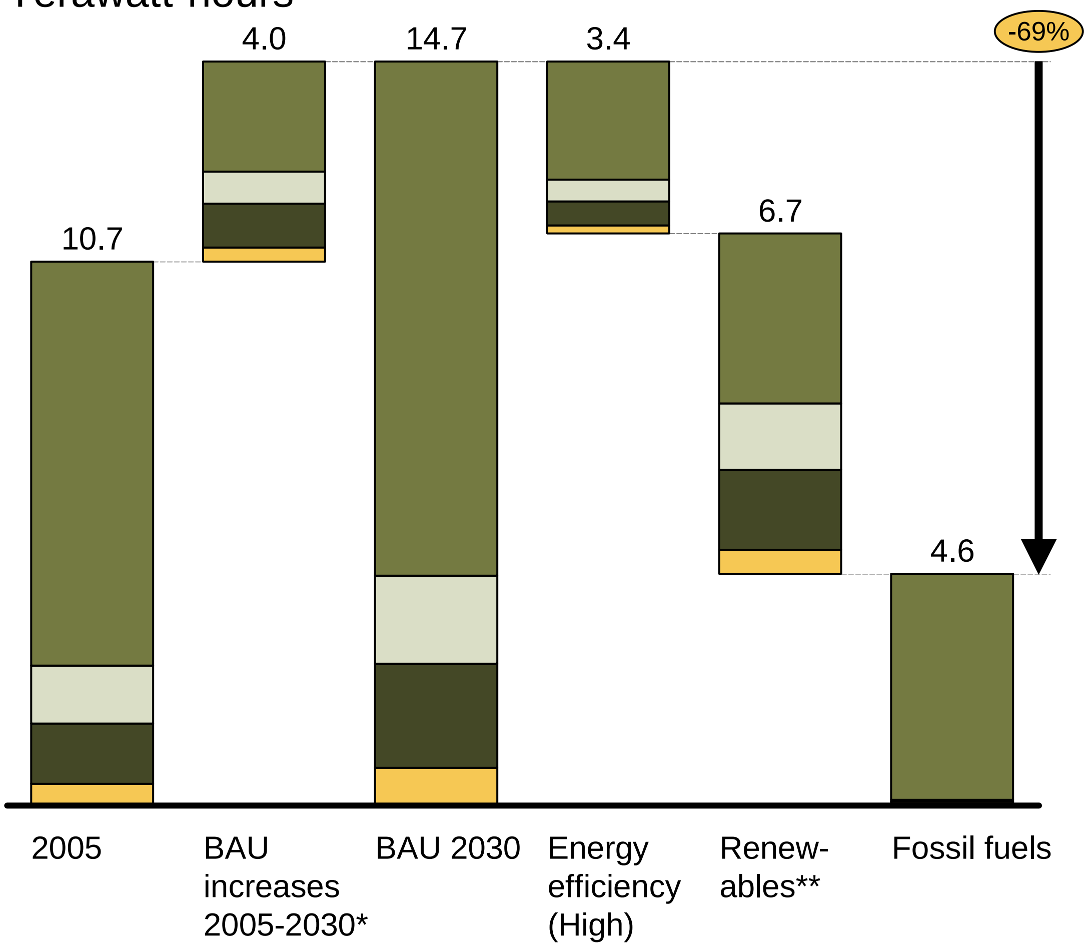
Limits greenhouse gas emissions to 1990 levels by 2020, not including airplanes. Charters a GHG emissions reduction taskforce and requires an updated inventory of GHG emissions

Source: Team analysis; literature search

ELECTRICITY: IN OUR HIGH CASE, 59% OF PROJECTED DEMAND COULD BE FULFILLED BY NON-FOSSIL FUEL GENERATION BY 2030

Electricity generation

Terawatt-hours



Generation from renewables, 2030

Percent

	Medium	High	High (all)
Oahu	12%	29%	43%
Big Island	86%	89%	99%
Maui+	73%	77%	99%
Kauai	68%	72%	83%
Overall	**32%**	**45%**	**59%**

Remaining Fossil Fuel Generation

TWh

Overall	**7.6**	**6.2**	**4.6**

- Oahu is limited by firming (little firmed wind and biomass as a percent of total capacity)
- Big Island has high percentage primarily because of on-demand geothermal
- Maui has a high relative proportion of firmed wind capacity
- Kauai has relatively high proportions of dispatchable biomass generation, but is still limited by amount of firm potential

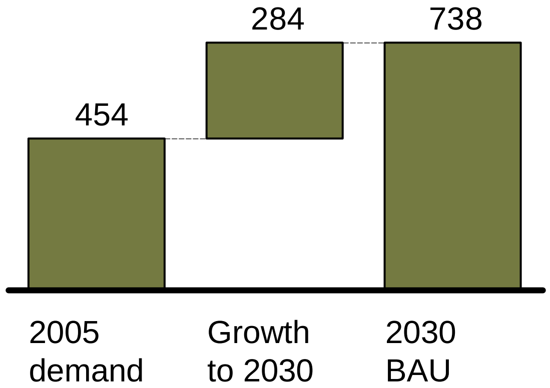
* BAU based on utility IRPs

** The High (all) case is shown, which includes all measures, including those costing more than $50/tCO2. Does not include 0.894 TWh of as-available generation to be used for PHEV charging. All numbers Include renewables that were already installed by 2005.

Source: Team analysis

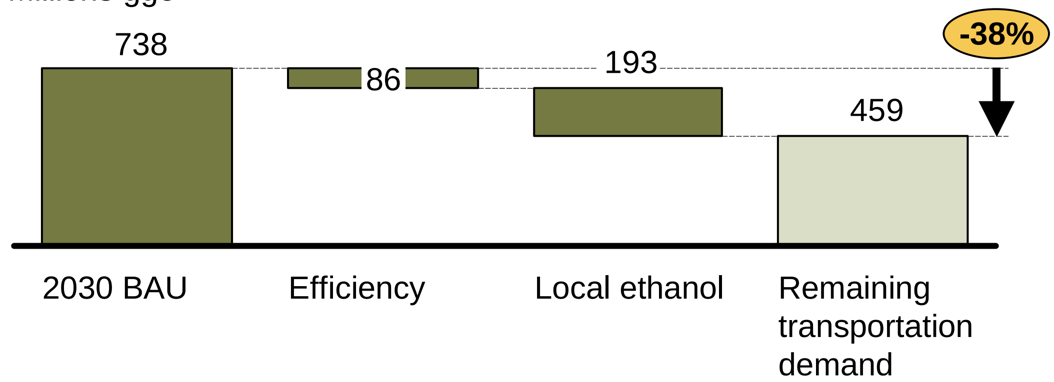
TRANSPORTATION: IMPROVED VEHICLE EFFICIENCY AND LOCALLY SOURCED ETHANOL WOULD ABATE ~40-80% OF GASOLINE DEMAND

BAU transportation demand
Millions gge



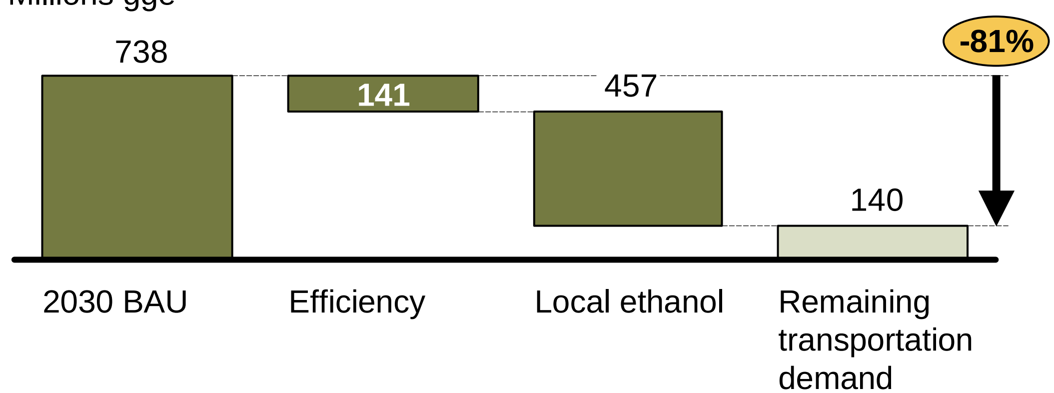
- 0% of gasoline demand is produced locally

Medium transport abatement case
Millions gge



- 30% of gasoline demand is produced locally

High transport abatement case
Millions gge

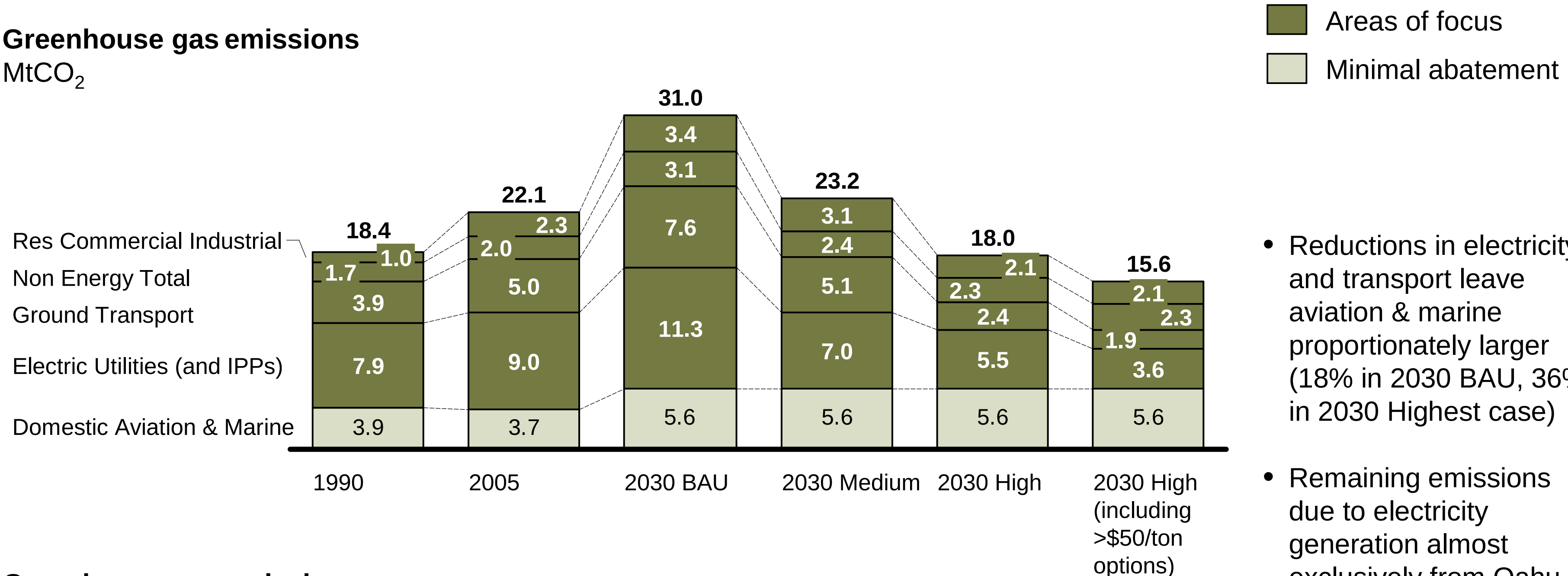


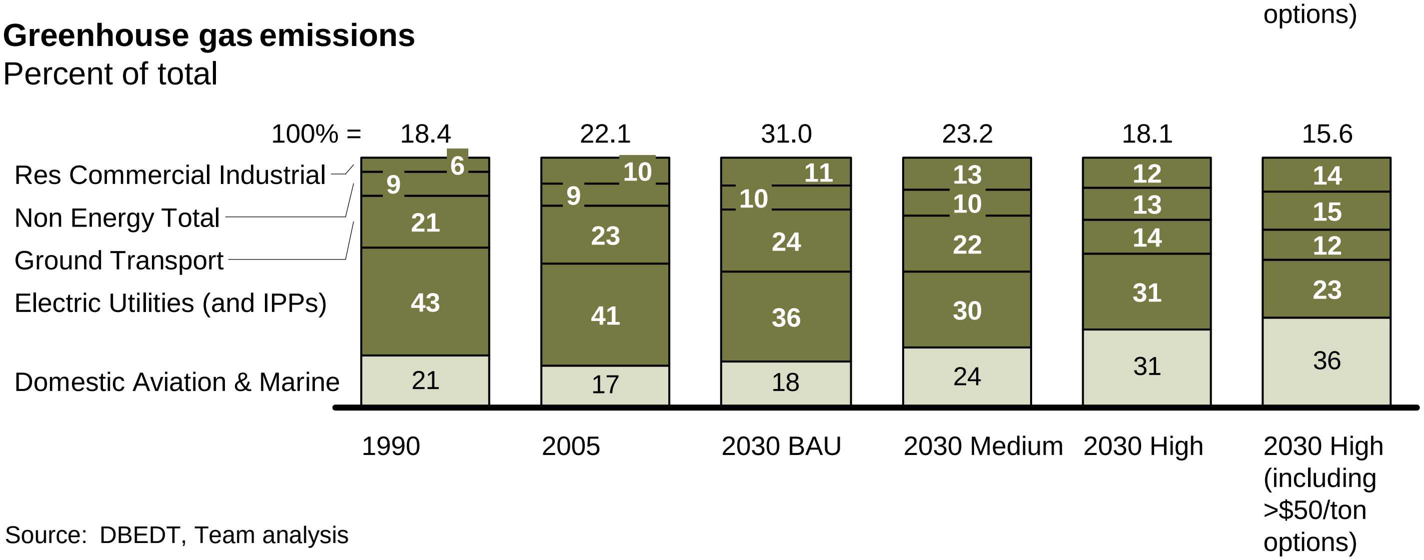
- 76% of gasoline demand is produced locally

* Assumes no adoption of biodiesel or electric-only vehicles

Source: RMI; DBEDT; McKinsey analysis

AGGRESSIVE ACTION CAN RETURN EMISSIONS TO 1990 LEVELS DESPITE CONTINUED GROWTH IN AVIATION AND MARINE



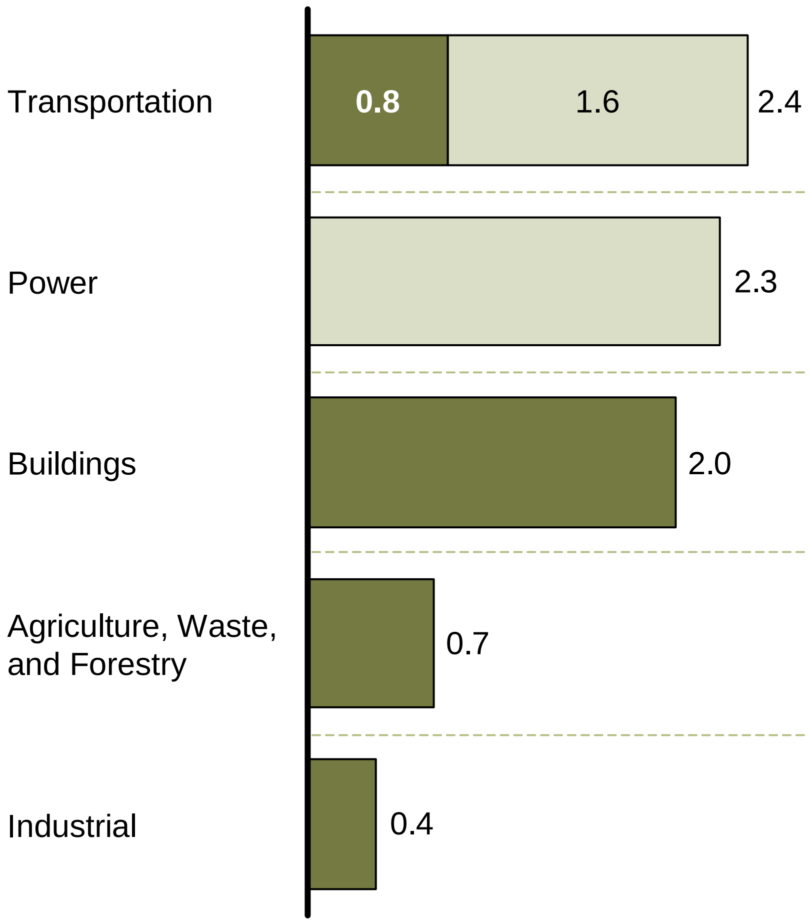


- Reductions in electricity and transport leave aviation & marine proportionately larger (18% in 2030 BAU, 36% in 2030 Highest case)
- Remaining emissions due to electricity generation almost exclusively from Oahu (57% of electricity still produced by fuel oil and coal in the High (all) case)

Source: DBEDT, Team analysis

ACHIEVING THIS LEVEL OF ABATEMENT REQUIRES CHANGES ACROSS SECTORS

Medium-case abatement potential
Mt CO_2e



Potential barriers to capture opportunity

Transportation:
- Risk from water rights/irrigation costs
- Inability to achieve scale for biofuels production (e.g., contiguous land, differential demand by island)
- Lack of incentive to improve efficiency in large fleets (e.g., rentals)

Power:
- Opposition to developing renewable energy sites (e.g., land ownership, NIMBY-ism)
- Difficulty in balancing intermittency of renewable sources
- Challenges obtaining funding for inter-island cable

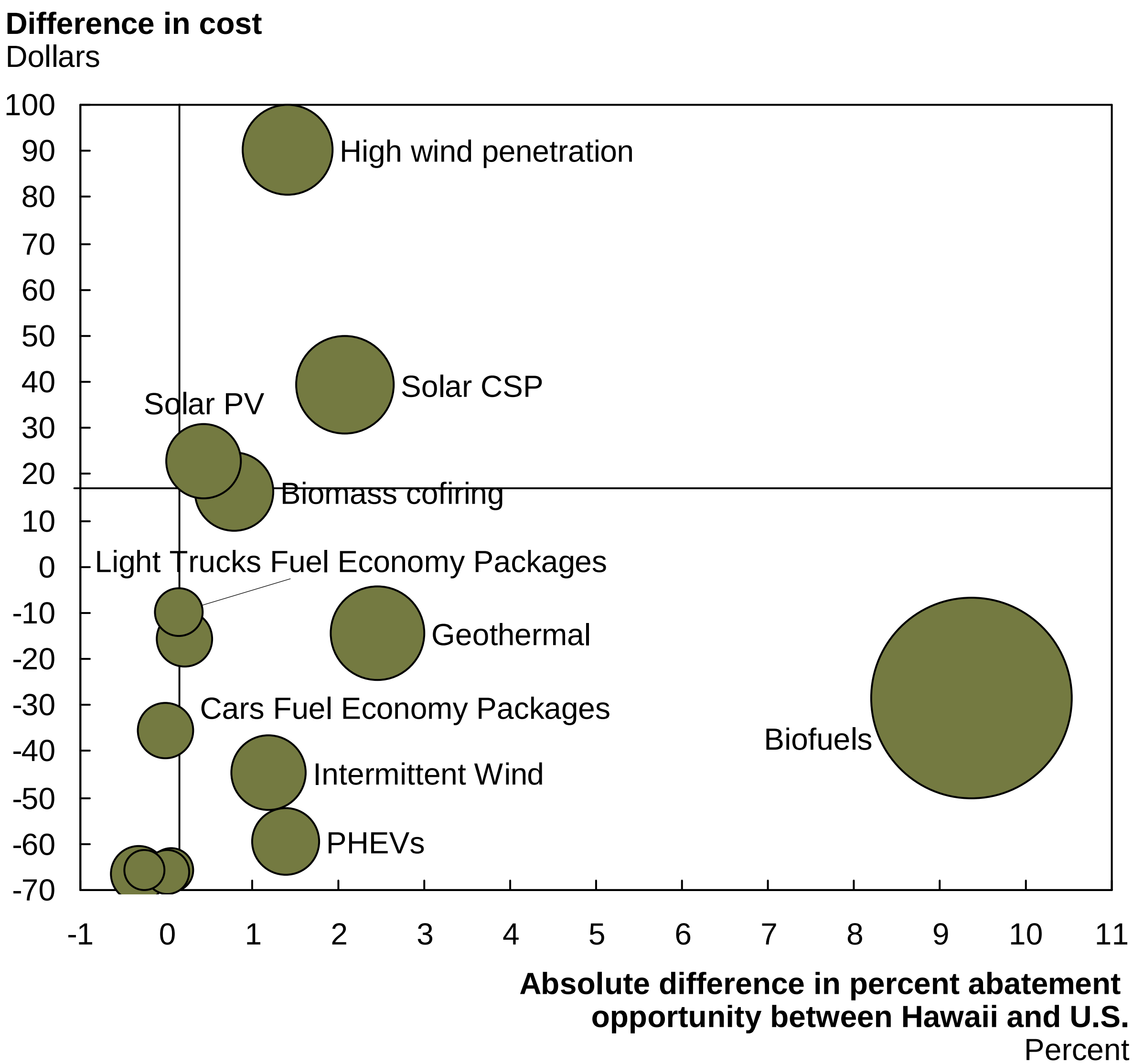
Buildings:
- Expectations of high returns on energy efficiency investments from businesses and consumers
- Principal/agent issues (e.g., developers make initial investment but do not pay ongoing operations costs)

Agriculture, Waste, and Forestry:
- Opposition to changes in land use (e.g., reduced land for grazing, encouraging denser timber stands, afforesting existing pasture land, and transition of some lands to higher carbon-intensity plants)

Industrial:
- Investments in incremental efficiency improvements may have lower ROI than other capital deployment options

BIOFUELS, WIND, AND GEOTHERMAL ARE MORE ATTRACTIVE OPPORTUNITIES IN HAWAII

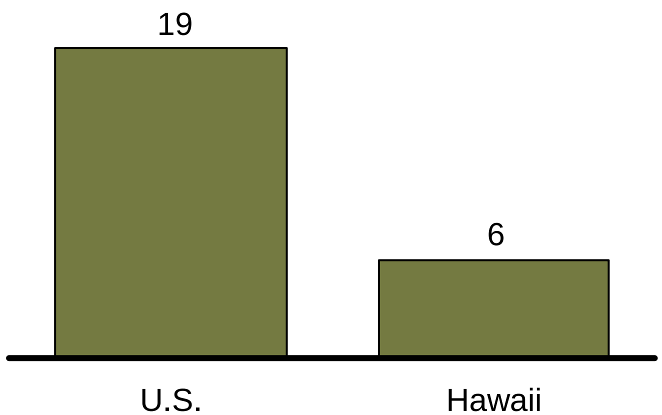
Hawaii abatement categories > 0.19Mt/yr



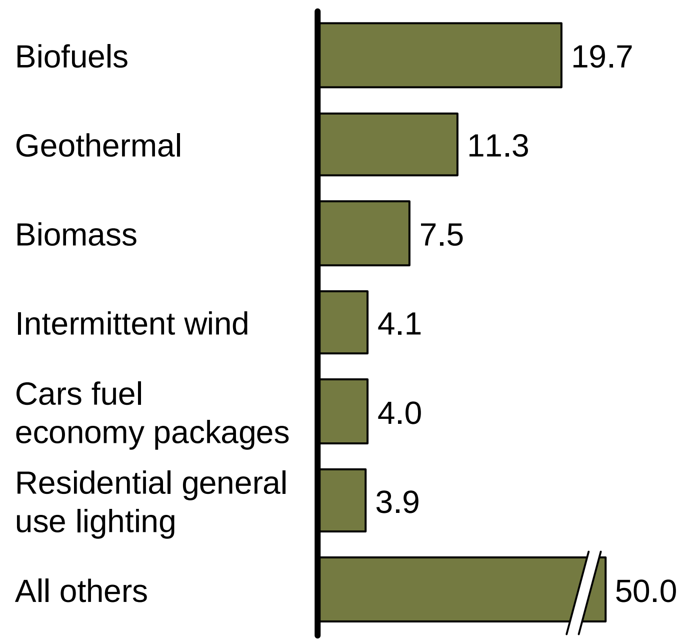
- Biofuels is a much larger opportunity than broader U.S. due to sugarcane productivity
- Hawaii has many unique resources (e.g., geothermal, intermittent wind, excess renewables to power PHEVs) that can be harnessed at lower cost than in the rest of the U.S.
- Due to high energy prices, efficiency measures (e.g., commercial electronics, fuel economy packages) are less expensive than in the U.S.
- However, Hawaii unique costs to connect isolated grids and manage intermittency, which causes wind and solar to be more expensive than the U.S.

ABATEMENT OPPORTUNITIES ARE MUCH MORE CONCENTRATED FOR HAWAII THAN THE U.S.

Hawaii requires 6 initiatives to achieve half of abatement potential *
# of initiatives required to reach 50% of abatement*



Top 6 GHG Abatement Initiatives for Hawaii
Percent of total abatement, medium case



- Hawaii has benefit of being able to focus on fewer, higher-impact initiatives than the U.S.
- Ensuring progress against these initiatives is critical to capturing full abatement potential

* Hawaii had 70 initiatives in total, while U.S. had 85. For HI, 80% of abatement from largest 19 initiatives, U.S. required 38 initiatives to reach 80% of abatement

Source: Team analysis

KEY DIFFERENCES IN ABATEMENT OPPORTUNITIES BETWEEN HAWAII AND U.S.

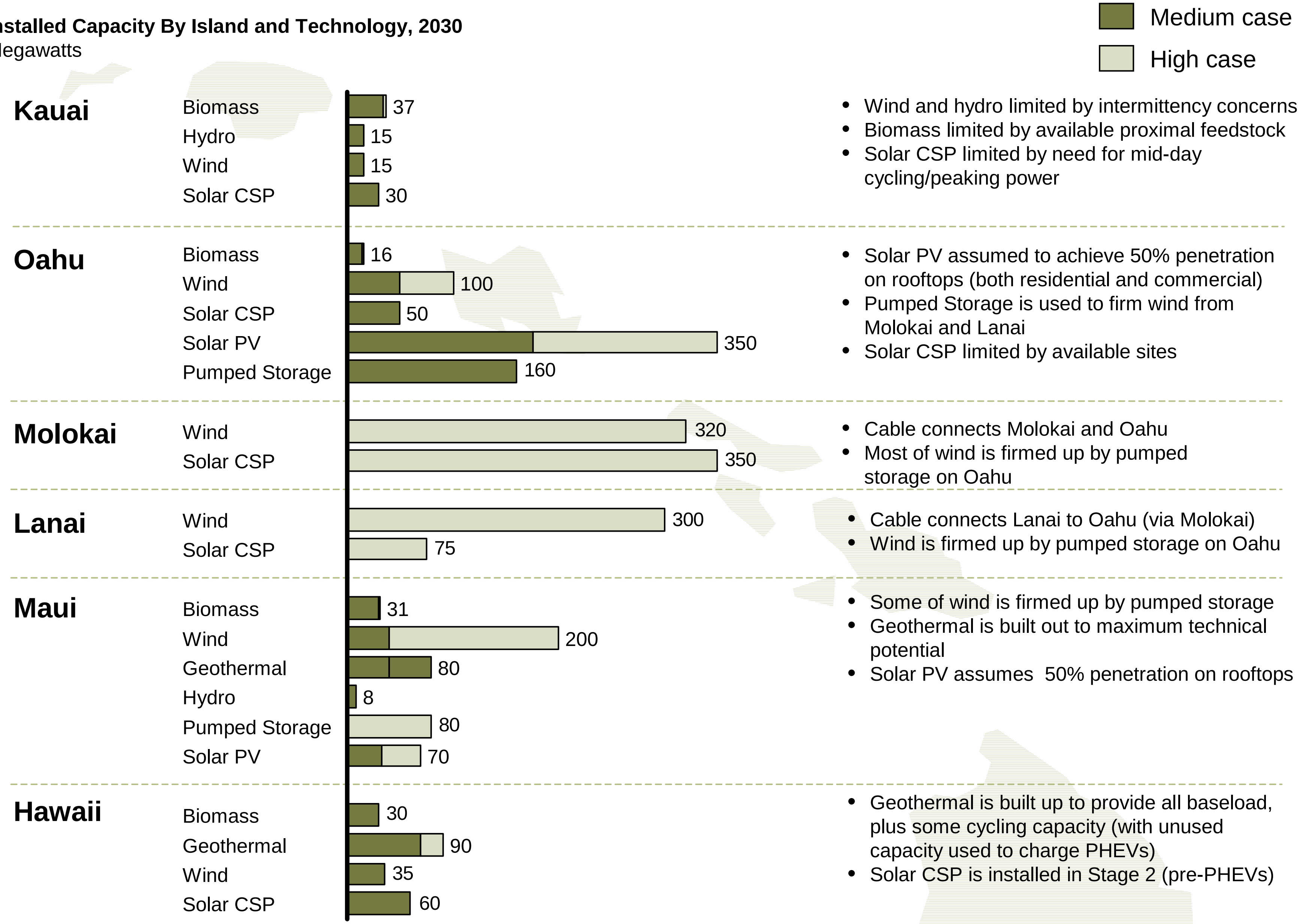
COMPARISON OF INITIATIVES <$50/TON

Sector		Medium case % of 2030 CO_2e emissions	High case % of 2030 CO_2e emissions	Key differences
Industrial	U.S.	6.6	8.2	• Hawaii has limited activity in the heavy industrial sector (chemicals, iron and steel, pulp and paper, cement, coal mining, fossil fuel extraction) • Relatively large refining capacity on Hawaii
	Hawaii	1.2	4.2	
Buildings	U.S.	7.5	9.1	• Hawaii-specific opportunities include solar water heating and sea water air conditioning • Limited space heating
	Hawaii	6.5	7.6	
Power	U.S.	9.1	18.5	• No CCS or significant coal-to-gas opportunity • Constitutional limitation on nuclear power • Significant potential for renewables, but isolated grid makes integrating large penetration of renewables expensive (>$50/t cutoff)
	Hawaii	7.3	10.9	
Transport	U.S.	4.2	8.4	• Significantly higher penetration of biofuels from in-state sugar and cellulosic ethanol production
	Hawaii	7.8	16.5	
AWF	U.S.	5.0	6.5	• Smaller active agricultural base than U.S.
	Hawaii	2.2	2.5	

Source: Team analysis

INCREMENTAL INSTALLATION OF TECHNOLOGIES VARIES BY ISLAND

Installed Capacity By Island and Technology, 2030
Megawatts



Kauai
- Wind and hydro limited by intermittency concerns
- Biomass limited by available proximal feedstock
- Solar CSP limited by need for mid-day cycling/peaking power

Oahu
- Solar PV assumed to achieve 50% penetration on rooftops (both residential and commercial)
- Pumped Storage is used to firm wind from Molokai and Lanai
- Solar CSP limited by available sites

Molokai
- Cable connects Molokai and Oahu
- Most of wind is firmed up by pumped storage on Oahu

Lanai
- Cable connects Lanai to Oahu (via Molokai)
- Wind is firmed up by pumped storage on Oahu

Maui
- Some of wind is firmed up by pumped storage
- Geothermal is built out to maximum technical potential
- Solar PV assumes 50% penetration on rooftops

Hawaii
- Geothermal is built up to provide all baseload, plus some cycling capacity (with unused capacity used to charge PHEVs)
- Solar CSP is installed in Stage 2 (pre-PHEVs)

Source: Team analysis

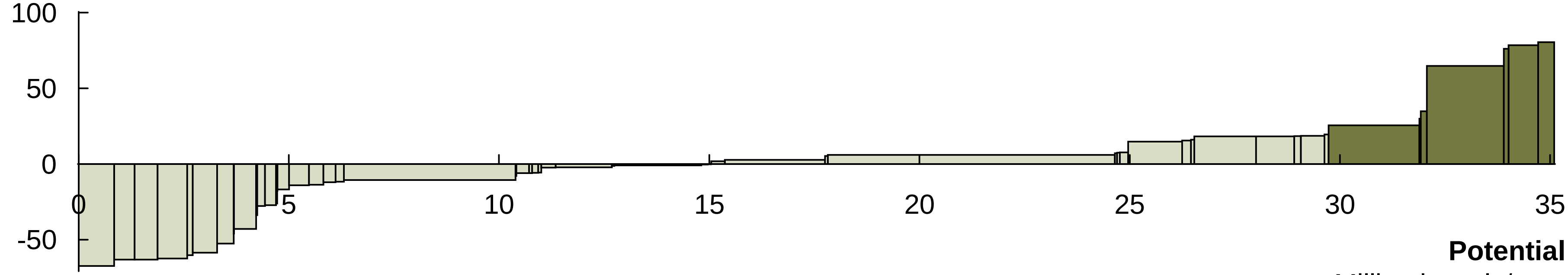
MOST OPTIONS BECOME COST EFFECTIVE AGAINST COST OF OIL AT $120/bbl

BASED ON HIGH GHG ABATEMENT CASE

Hawaii oil abatement curve at $60/bbl (15.6 mbbl oil abatement opportunity)

CO_2 Abatement cost <$50/ton

Cost
Real 2005 dollars per barrel abated

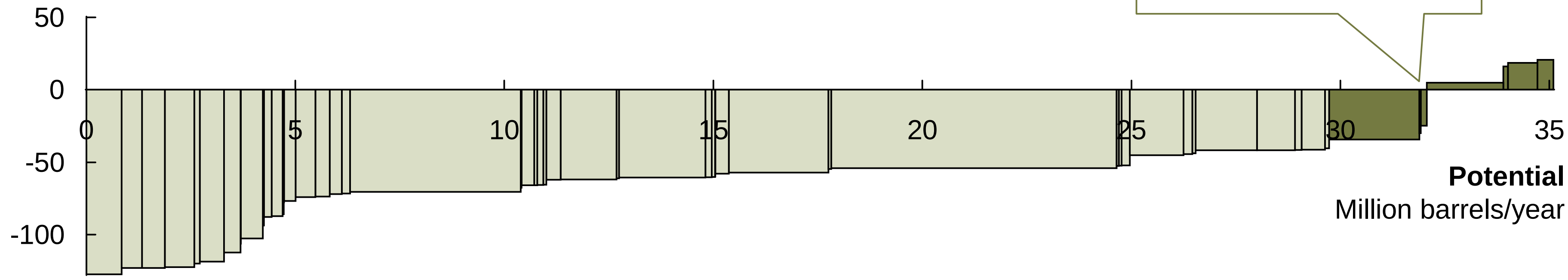


Potential
Million barrels/year

Hawaii Oil abatement curve at $120/bbl (35.7 mbbl oil abatement opportunity)

Cost
Real 2005 dollars per barrel abated

At $120/bbl, nearly all abatement opportunities provide economic benefit



Potential
Million barrels/year

Source: Team analysis

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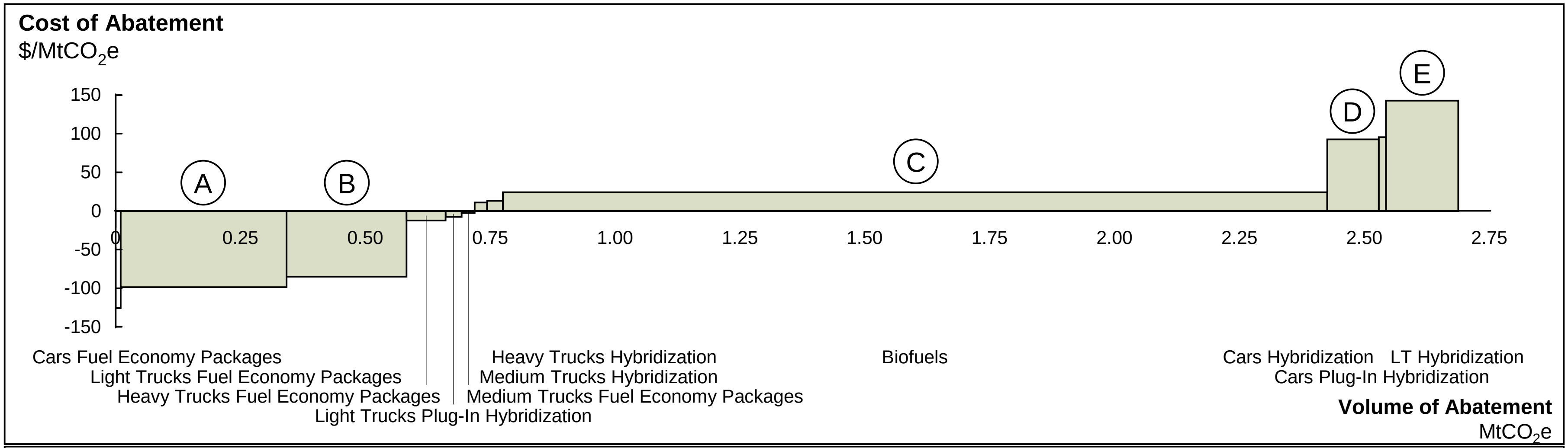
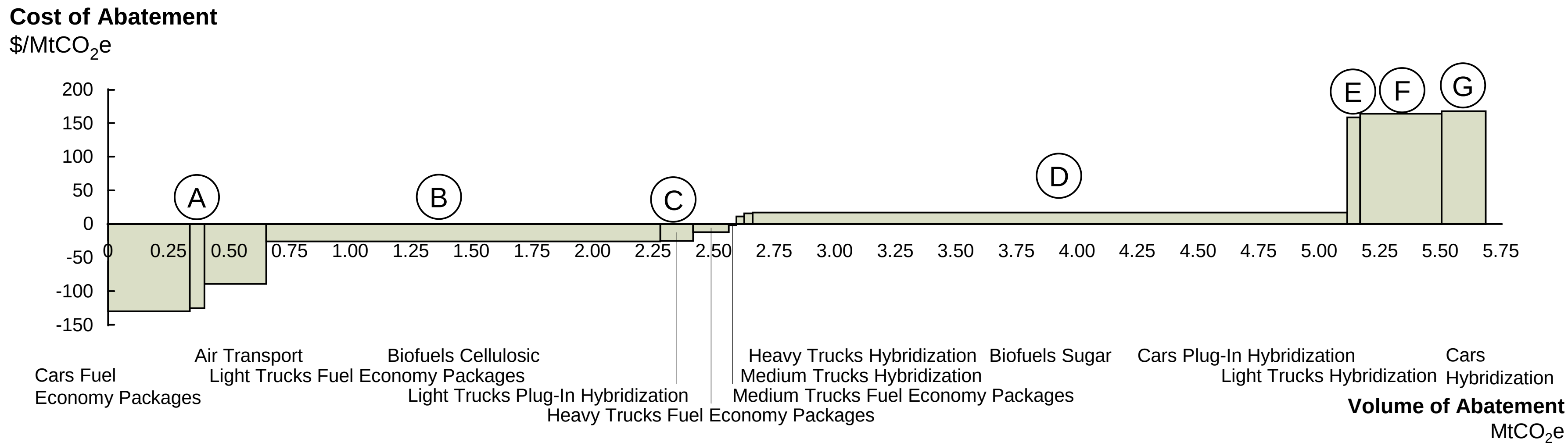
TRANSPORTATION SECTOR ABATEMENT – MEDIUM CASE



	Opportunity	Abatement $MtCO_2e$	Cost $/MtCO2e	Key Assumptions	Scaling Methodology
A	Cars Fuel Economy Packages	0.33	-98.59	• Significant fuel economy from improvements to conventional ICE can be achieved, going from 23 to 31 average miles per gallon	• US data scaled to reflect Hawaii fleet stock and VMT profile
B	Light Trucks Fuel Economy Packages	0.24	-85.23	• Significant fuel economy from improvements to conventional ICE can be achieved, going from 17 to 22 average miles per gallon	• US data scaled to reflect Hawaii fleet stock and VMT profile
C	Biofuels	1.65	24.05	• Sugarcane planting at 1969 acreage levels (242,000), including restoration of irrigation systems • Excess bagasse converted to electricity and sold back to the grid	• Hawaii-specific analysis
D	Cars Hybridization	0.10	95.40	• Penetration of hybrid cars reaches 30% of new sales in 2030 and 20% of total fleet VMT	• US data scaled to reflect Hawaii fleet stock and VMT profile
E	Light Truck Hybridization	0.14	142.87	• Penetration of hybrid light trucks reaches 30% of new sales in 2030 and 23% of total fleet VMT	• US data scaled to reflect Hawaii fleet stock and VMT profile

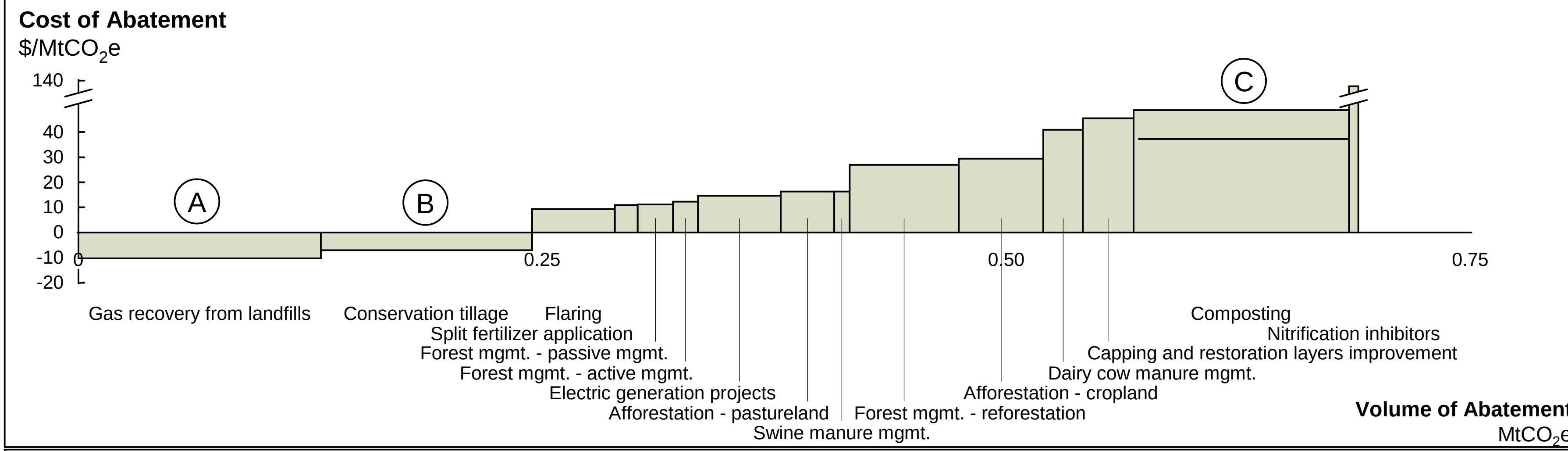
TRANSPORTATION SECTOR ABATEMENT – HIGH CASE



	Opportunity	Abatement $MtCO_2e$	Cost $/MtCO2e	Key Assumptions	Scaling Methodology
A	Fuel Economy Packages	0.34 (cars) 0.25 (LT)	-130.13 (cars) -89.10 (LT)	• Earlier penetration of more aggressive packages than mid-range case	• US data scaled to reflect Hawaii fleet stock and VMT profile
B	Biofuels Cellulosic	1.63	-26.10	• 2 cellulosic plants built on Big Island using woody crops on ag-zoned land	• Hawaii-specific analysis
C	LT Plug-In Hybridization	0.14	-25.07	• 50% of new sales in 2030 are PHEV, powered by renewable sources	• Hawaii-specific analysis
D	Biofuels Sugar	2.57	16.76	• Sugarcane planting at maximum acreage levels (360,000) • Excess bagasse converted to electricity and sold back to the grid	• Hawaii-specific analysis
E	Cars Plug-In Hybridization	0.06	158.92	• 50% of new sales in 2030 are PHEV, powered by renewable sources	• Hawaii-specific analysis
F	Cars Hybridization	0.18	168.12	• Penetration of hybrid cars reaches 59% of new sales in 2030 and 40% of total fleet VMT	• US data scaled to reflect Hawaii fleet stock and VMT profile
G	LT Hybridization	0.33	163.94	• Penetration of hybrid light trucks reaches 70% of new sales in 2030 and 50% of total fleet VMT	• US data scaled to reflect Hawaii fleet stock and VMT profile

Source: Team Analysis

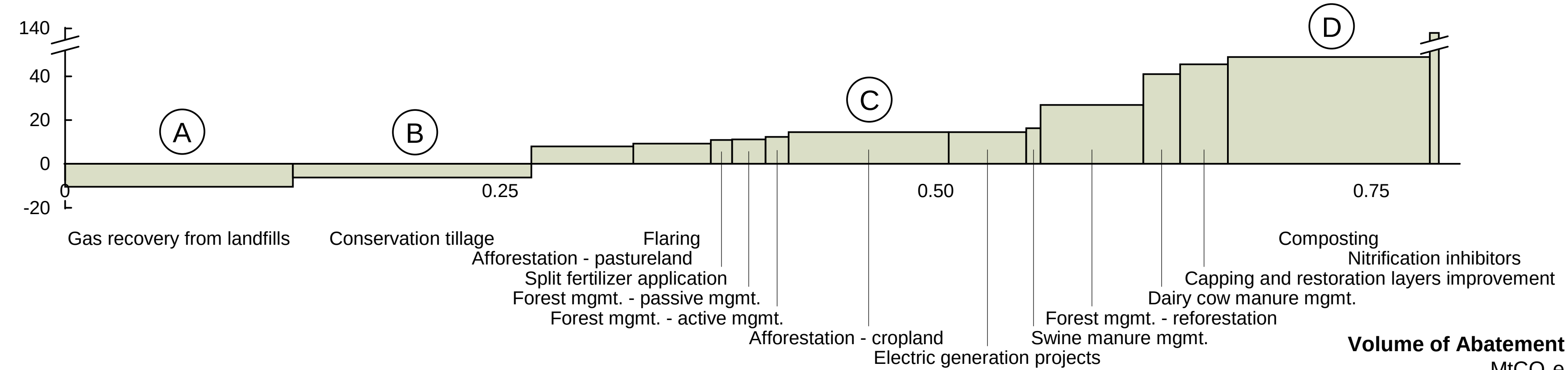
AWF SECTOR ABATEMENT – MEDIUM CASE



	Opportunity	Abatement $MtCO_2e$	Cost $/MtCO2e	Key Assumptions	Scaling Methodology
A	Gas recovery from landfills	0.13	-10.41	• Emissions already declining in BAU due to improvements and legislation, but some abatement potential remains especially with smaller landfill sites not covered by legislation	• US data scaled to Hawaii based on Hawaii's waste profile
B	Conservation tillage	0.11	-7.11	• Soil management opportunities are low-cost and offer abatement potential	• US data scaled to Hawaii based on Hawaii's agricultural profile
C	Composting	0.12	48.85	• Agricultural management practices in composting and manure management offer abatement potential	• US data scaled to Hawaii based on Hawaii's agricultural profile

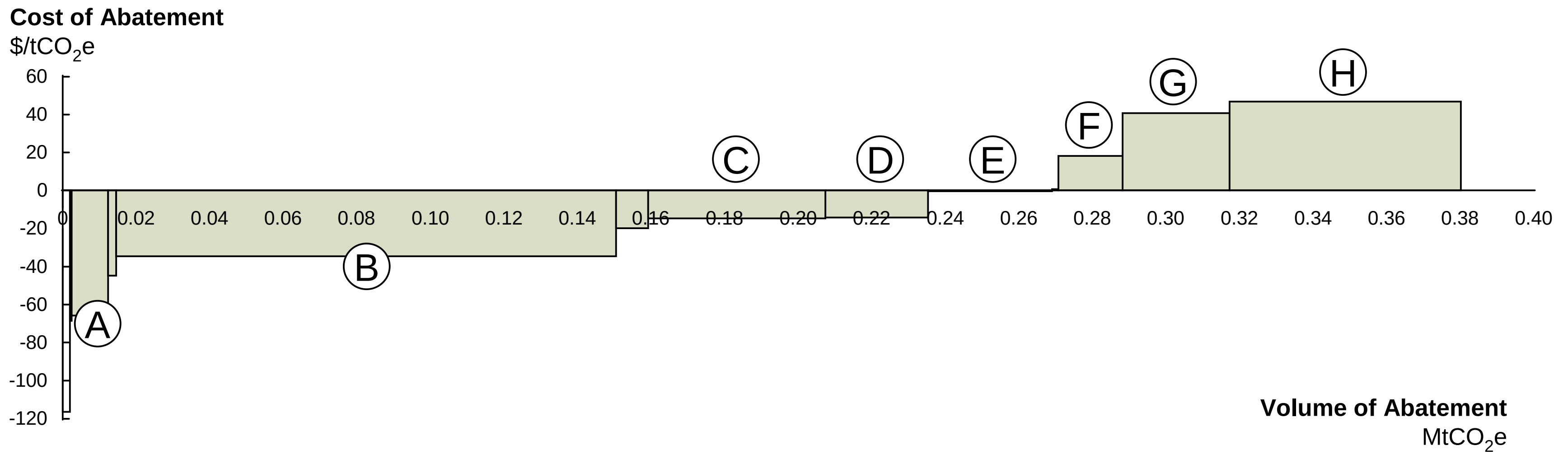
Source: Team Analysis

AWF SECTOR ABATEMENT – HIGH CASE



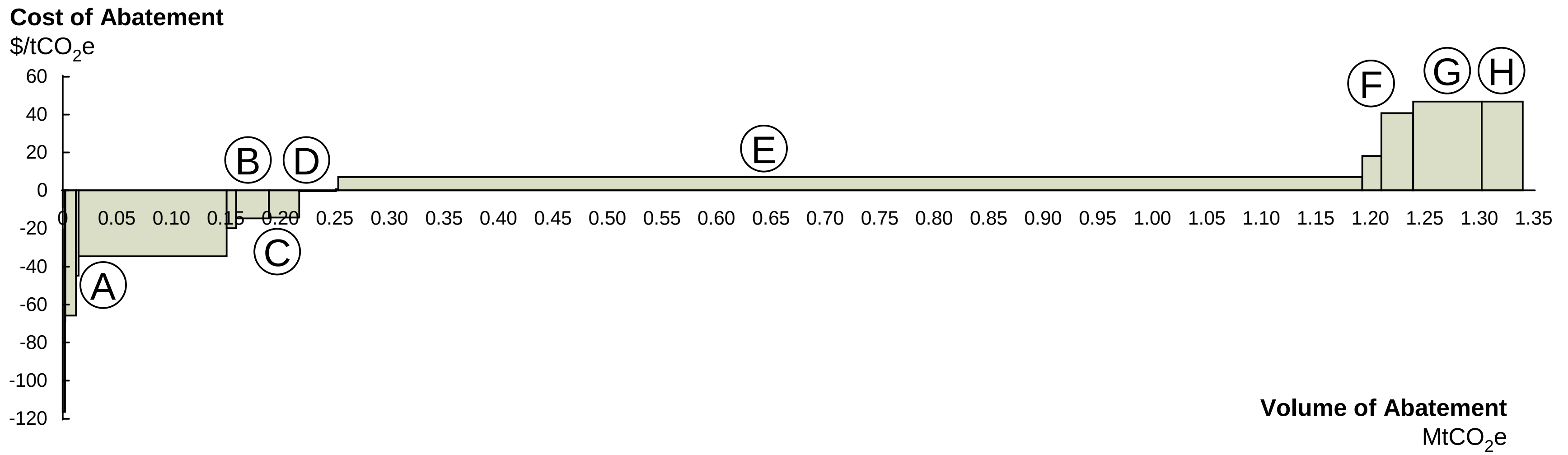
	Opportunity	Abatement $MtCO_2e$	Cost $/MtCO2e	Key Assumptions	Scaling Methodology
A	Gas recovery from landfills	0.13	-10.41	• Emissions already declining in BAU due to improvements and legislation, but some abatement potential remains especially with smaller landfill sites not covered by legislation	• US data scaled to Hawaii based on Hawaii's waste profile
B	Conservation tillage	0.14	-6.16	• Soil management opportunities are low-cost and offer abatement potential	• US data scaled to Hawaii based on Hawaii's agricultural profile
C	Afforestation - cropland	0.09	14.60	• Cropland afforestation offers a carbon sink opportunity as fallow land becomes planted	• US data scaled to Hawaii based on Hawaii's forestry profile
D	Composting	0.12	48.85	• Agricultural management practices in composting and manure management offer abatement potential	• US data scaled to Hawaii based on Hawaii's agricultural profile

INDUSTRIAL SECTOR – MEDIUM CASE



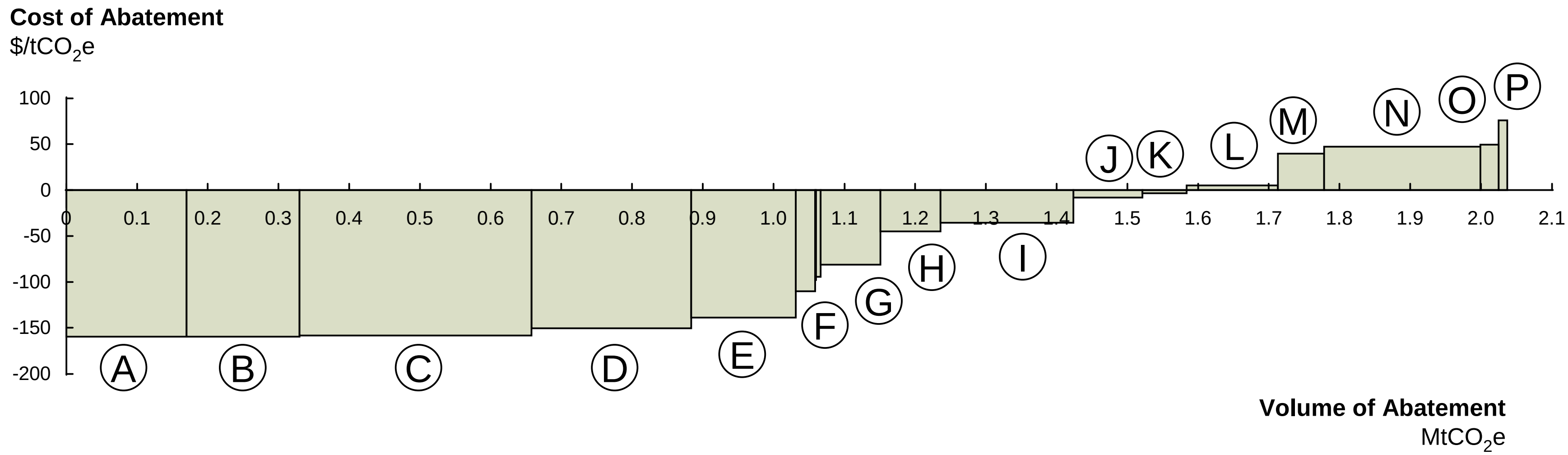
	Opportunity	Abatement $MtCO_2e$	Cost $/tCO2e	Key Assumptions	Scaling Methodology
A	Electric Motor Systems	0.01	-66	• 3% improvement in effficiency vs. BAU	• Scaled from US curve based on relative manufacturing GDP and refining capacity
B	Fired/Steam Improvements	0.14	-35	• 3 % improvement in efficiency vs. BAU	
C	CHP	0.05	-15	• 40 MW incremental to BAU	
D	Reduce Fouling	0.03	-14	• 4% improvement in efficiency vs. BAU	
E	HFCs	0.03	-0	• 10% improvement in HFC capture	
F	Manage hot feeds	0.02	18	• 2.5% improvement in efficiency vs. BAU	
G	Adv. Proc. Ctrl	0.03	41	• 4% improvement in efficiency vs. BAU	
H	Energy Recovery	0.06	47	• 4% improvement in efficiency vs. BAU	

INDUSTRIAL SECTOR – HIGH CASE



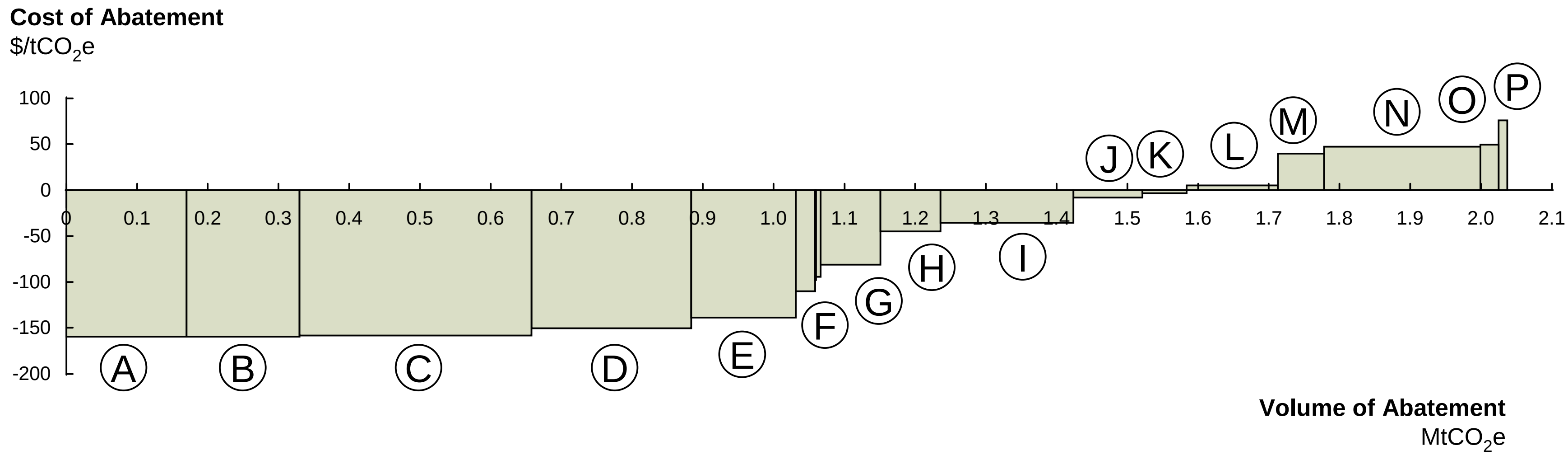
	Opportunity	Abatement $MtCO_2e$	Cost $/tCO2e	Key Assumptions	Scaling Methodology
A	Fired/Steam Improvements	0.12	-34	• 4 % improvement in efficiency vs. BAU	• Scaled from US curve based on relative manufacturing GDP and refining capacity ↓
B	CHP	0.03	-15	• 25 MW incremental to BAU	
C	Reduce Fouling	0.03	-14	• 5% improvement in efficiency vs. BAU	
D	HFCs	0.03	-0	• 10% improvement in HFC capture	
E	Oil Refining	0.94	7	• Eliminated need for 80Mbbl/day of oil refining due to other abatement opportunities	• Hawaii-specific analysis
F	Manage hot feeds	0.02	18	• 3% improvement in efficiency vs. BAU	• Scaled from US curve based on relative manufacturing GDP and refining capacity ↓
G	Adv. Proc. Ctrl	0.03	41	• 5% improvement in efficiency vs. BAU	
H	Energy Recovery	0.06	47	• 5% improvement in efficiency vs. BAU	

BUILDING SECTOR – MEDIUM CASE (1/2)



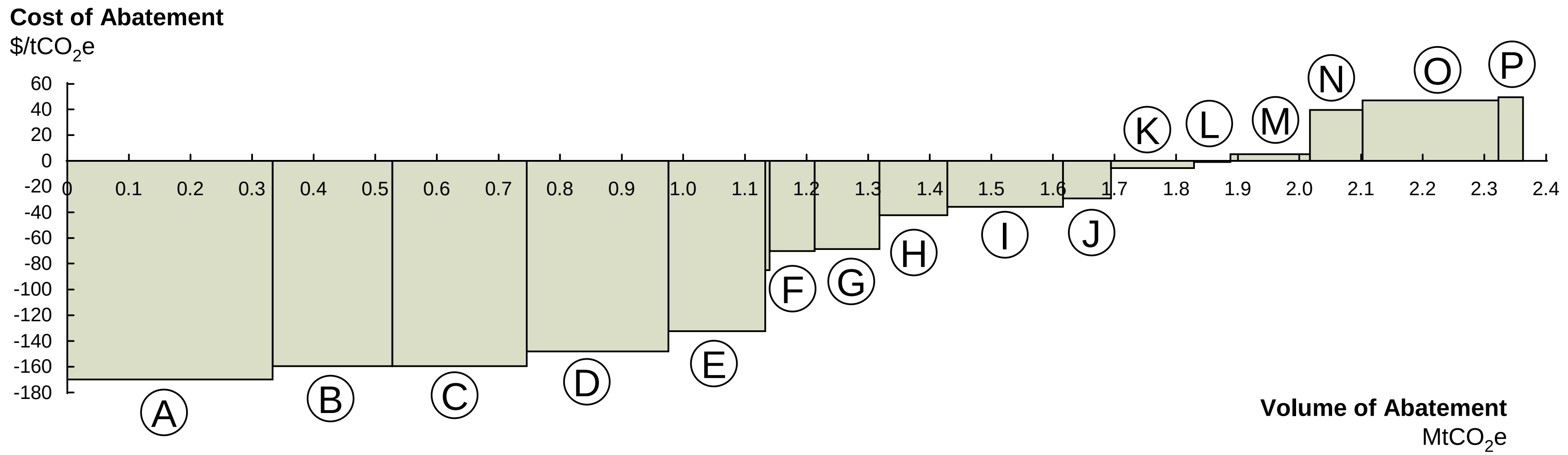
Opportunity	Abatement $MtCO_2e$	Cost $/tCO2e	Key Assumptions	Scaling Methodology
(A) Comm. Electronics	0.17	-159	• PCs, office equipment efficiency improved 25% over BUA	• Scaled from US curve based on number of households and commercial square footage ↓
(B) Res. Electronics	0.16	-159	• PCs, TVs, Set-top boxes improved 29% from BAU	
(C) Res. Lighting	0.33	-158	• Standard incandescants are phased out in favor of CFLs (24%) and LEDs (46%) by 2030	
(D) Comm. LED	0.23	-151	• LED replacement of commercial lighting	
(E) Comm. T8	0.15	-139	• Super T8 systems replacing standard T8s with lamp and ballast changes	
(F) Refrigerators	0.03	-110	• 10% more efficient through increased insulation and improved compressor performance	
(G) Comm. Shell	0.08	-81	• Improved insulation in 1/3 of building stock	
(H) Non-Fridge Appliances	0.09	-45	• Major efficiency improvements in laundry (33%), and dishwashers (18%) over BAU	

BUILDING SECTOR – MEDIUM CASE (2/2)



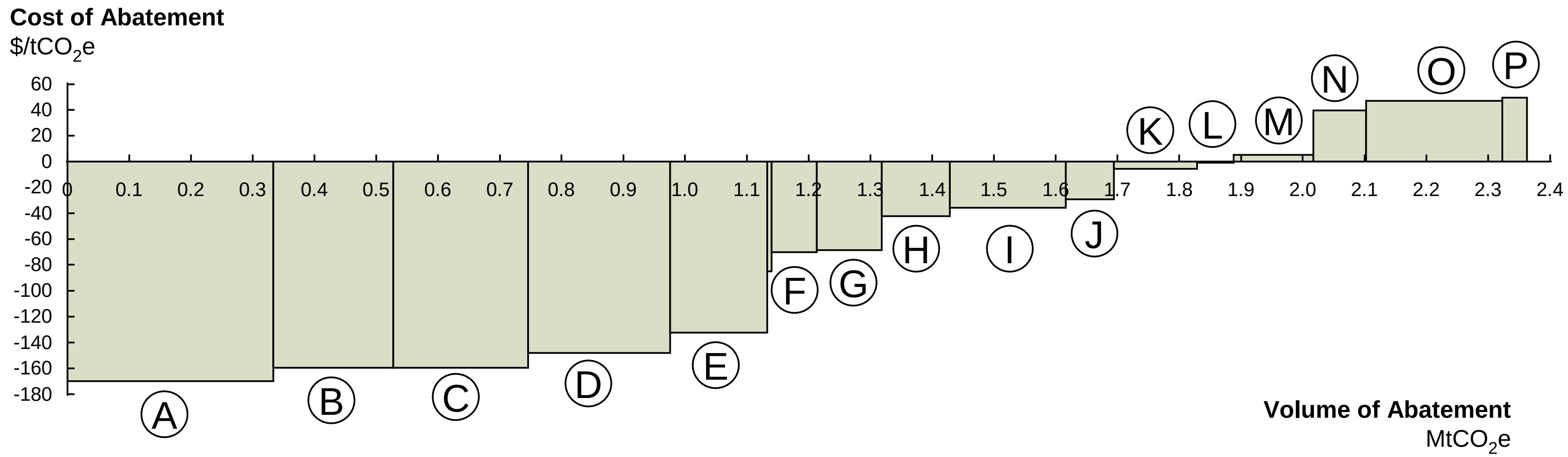
Opportunity	Abatement $MtCO_2e$	Cost $/tCO2e	Key Assumptions	Scaling Methodology
(I) CHP/Tri-Gen	0.19	-35	• 150 MW of capacity	• Scaled from US curve based on number of households and commercial square footage ↓
(J) Res. Water heaters	0.10	-8	• Move to gas where available and improved technology	
(K) Control Systems	0.06	-3	• 10-20% savings for demand controlled ventilation, sensor controleld lights, etc…	
(L) Solar Water heaters	0.13	5	• Incremental 70k systems beyond BAU	• Hawaii-specific analysis
(M) Comm. HVAC equip. eff.	0.07	39	• SEER 13.5 to SEER 15	• Scaled from US curve
(N) Sea Water AC	0.22	47	• Installation of four 80 GW equivalent systems	• Hawaii-specific analysis
(O) Res. HVAC Eff.	0.03	49	• SEER 13.5 to SEER 15	• Scaled from US curve
(P) Res. Retrofit HVAC	0.01	76	• Improved insulation	• Scaled from US curve

BUILDING SECTOR – HIGH CASE (1/2)



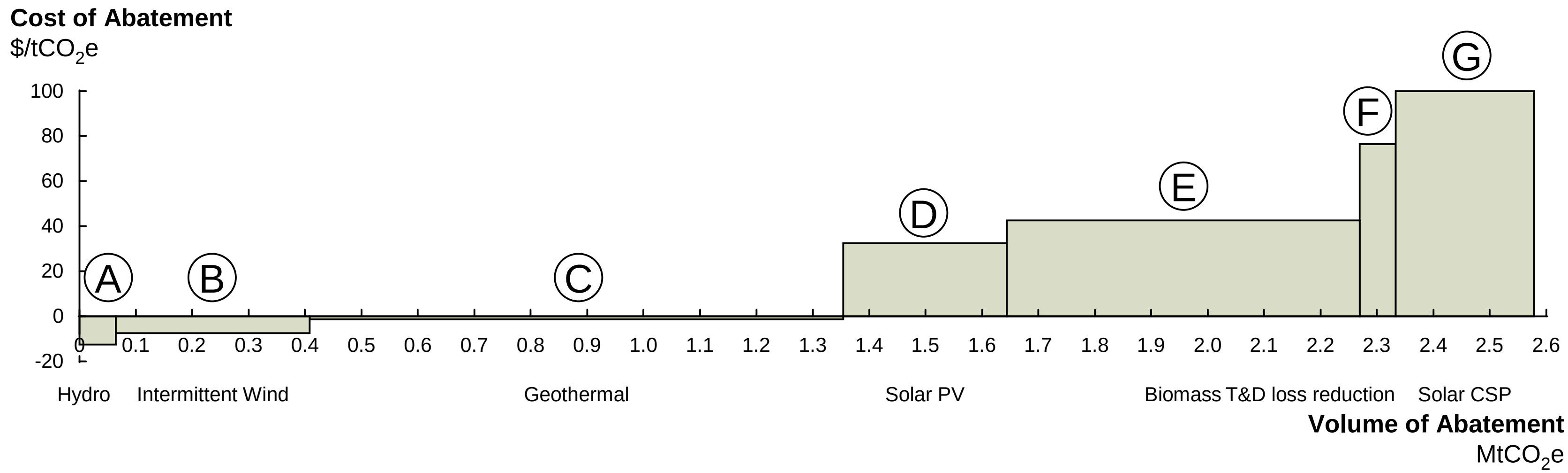
	Opportunity	Abatement MtCO$_2$e	Cost $/tCO2e	Key Assumptions	Scaling Methodology
A	Res. Lighting	0.33	-170	• Standard incandescants are phased out in favor of CFLs (24%) and LEDs (46%) by 2030	• Scaled from US curve based on number of households and commercial square footage
B	Comm. Electronics	0.19	-159	• PCs, office equipment efficiency improved 25% over BAU	
C	Res. Electronics	0.22	-159	• PCs, TVs, Set-top boxes improved 29% from BAU	
D	Comm. LED	0.23	-148	• LED replacement of commercial lighting	
E	Comm. T8	0.16	-132	• Super T8 systems replacing standard T8s with lamp and ballast changes	
F	Res. NB HVAC	0.07	-70	• 10% more efficient through increased insulation and improved compressor performance	
G	Comm. Shell	0.11	-69	• Improved insulation in 1/3 of building stock	
H	Non-Fridge Appliances	0.11	-42	• Major efficiency improvements in laundry (33%), and dishwashers (18%) over BAU	

BUILDING SECTOR – HIGH CASE (2/2)



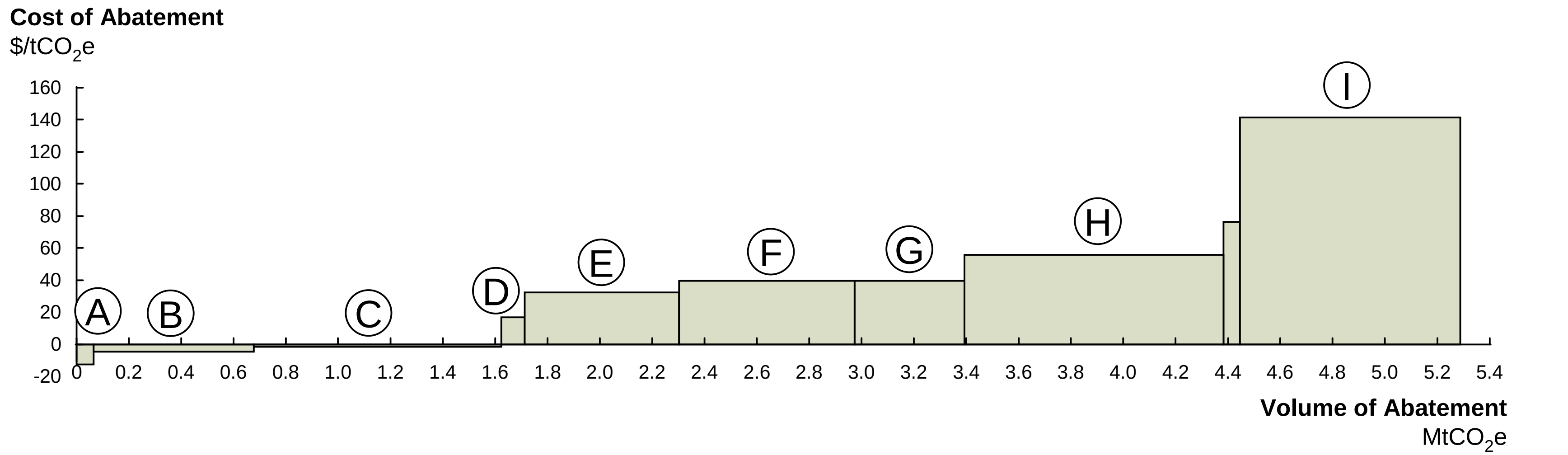
Opportunity	Abatement $MtCO_2e$	Cost $/tCO2e	Key Assumptions	Scaling Methodology
(I) CHP/Tri-Gen	0.19	-35	• 150 MW of capacity	• Scaled from US curve based on number of households and commercial square footage ↓
(J) Control Systems	0.08	-29	• 10-20% savings for demand controlled ventilation, sensor controleld lights, etc…	
(K) Res. Water Heater	0.13	-6	• Move to gas where available and improved technology	
(L) Refrigerators	0.06	-1	• 10% more efficient through increased insulation and improved compressor performance	
(M) Solar Water Heaters	0.13	5	• Incremental 70k systems beyond BAU	• Hawaii-specific analysis
(N) Comm. HVAC Eff.	0.09	39	• SEER 13.5 to SEER 15	• Scaled from US curve
(O) Sea Water AC	0.22	47	• Installation of four 80 GW equivalent systems	• Hawaii-specific analysis
(P) Res. HVAC Eff.	0.04	49	• SEER 13.5 to SEER 15	• Scaled from US curve

POWER SECTOR – MEDIUM CASE



	Opportunity	Abatement MtCO$_2$e	Cost $/tCO2e	Key Assumptions	Scaling Methodology
A	Small Hydro	0.06	-13	• 23 MW on Kauai and Maui	• Hawaii-specific analysis
B	Interm. WInd	0.34	-8	• 140 MW total, limited to 15% of peak demand or availably sites	• Hawaii-specific analysis
C	Geothermal	0.95	-2	• 150 MW incremental on Hawaii and Maui	• Hawaii-specific analysis
D	Solar PV	0.29	32	• 207 MW installed on Maui and Oahu	• Hawaii-specific analysis
E	Biomass	0.62	43	• 105 MW from Banagrass and byproduct of ethanol production	• Hawaii-specific analysis
F	T&D Losses	0.06	76	• Incremental improvements in T&D infrastructure	• Scaled from US curve
F	Solar CSP	0.25	100	• 140 MW installed	• Hawaii-specific analysis

POWER SECTOR – HIGH CASE



Opportunity	Abatement $MtCO_2e$	Cost $/tCO2e	Key Assumptions	Scaling Methodology
(A) Small Hydro	0.06	-13	• 23 MW on Kauai and Maui	• Hawaii-specific analysis
(B) Interm. WInd	0.61	-5	• 250 MW total, limited to about 15% of peak demand	• Hawaii-specific analysis
(C) Geothermal	0.95	-2	• 150 MW incremental on Hawaii and Maui	• Hawaii-specific analysis
(D) PHEV Geo	0.09	17	• Average of 20 MW used to charge 21k PHEVs	• Hawaii-specific analysis
(E) Solar PV	0.59	32	• 420 MW installed on Oahu and Maui	• Hawaii-specific analysis
(F) Biomass	0.67	40	• 113 MW from banagrass and byproduct of ethanol production	• Hawaii-specific analysis
(G) PHEV Wind	0.42	40	• 240 MW on Lanai to charge 100k PHEVs on Oahu/Maui complex	• Hawaii-specific analysis
(H) Solar CSP	0.99	56	• 565 MW with backup	• Hawaii-specific analysis
(I) Firm Wind	0.84	141	• 480 MW of wind using 240 MW of pumped storage	• Hawaii-specific analysis