Public Workshop
Carbon Capture and Sequestration

California Air Resources Board

Sacramento, California

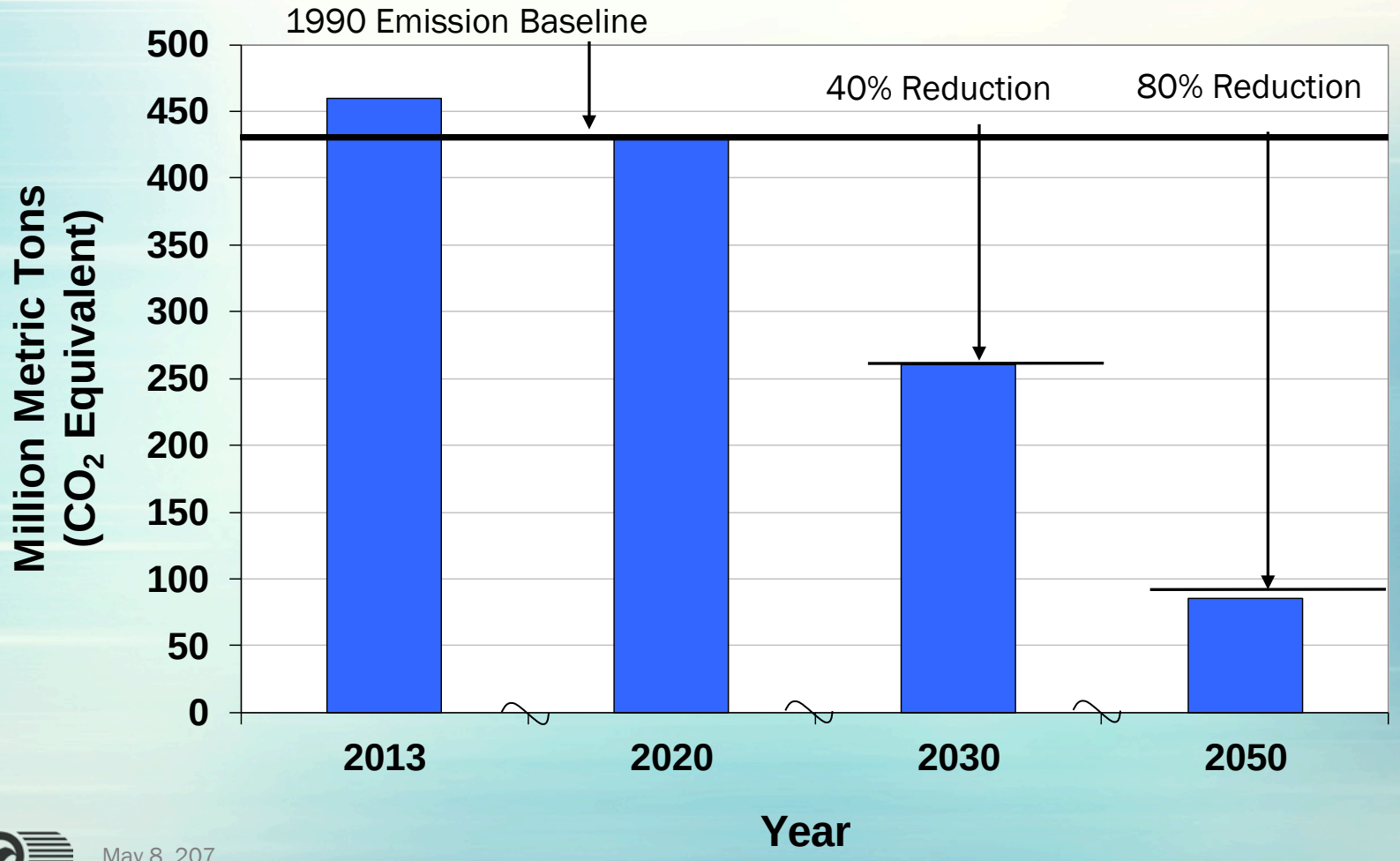
May 8, 2017

Agenda

- Background
- Recent CCS Activities
- Overview of CCS Concept
- Permanence Protocol
- Quantification Methodology
- Next steps

BACKGROUND

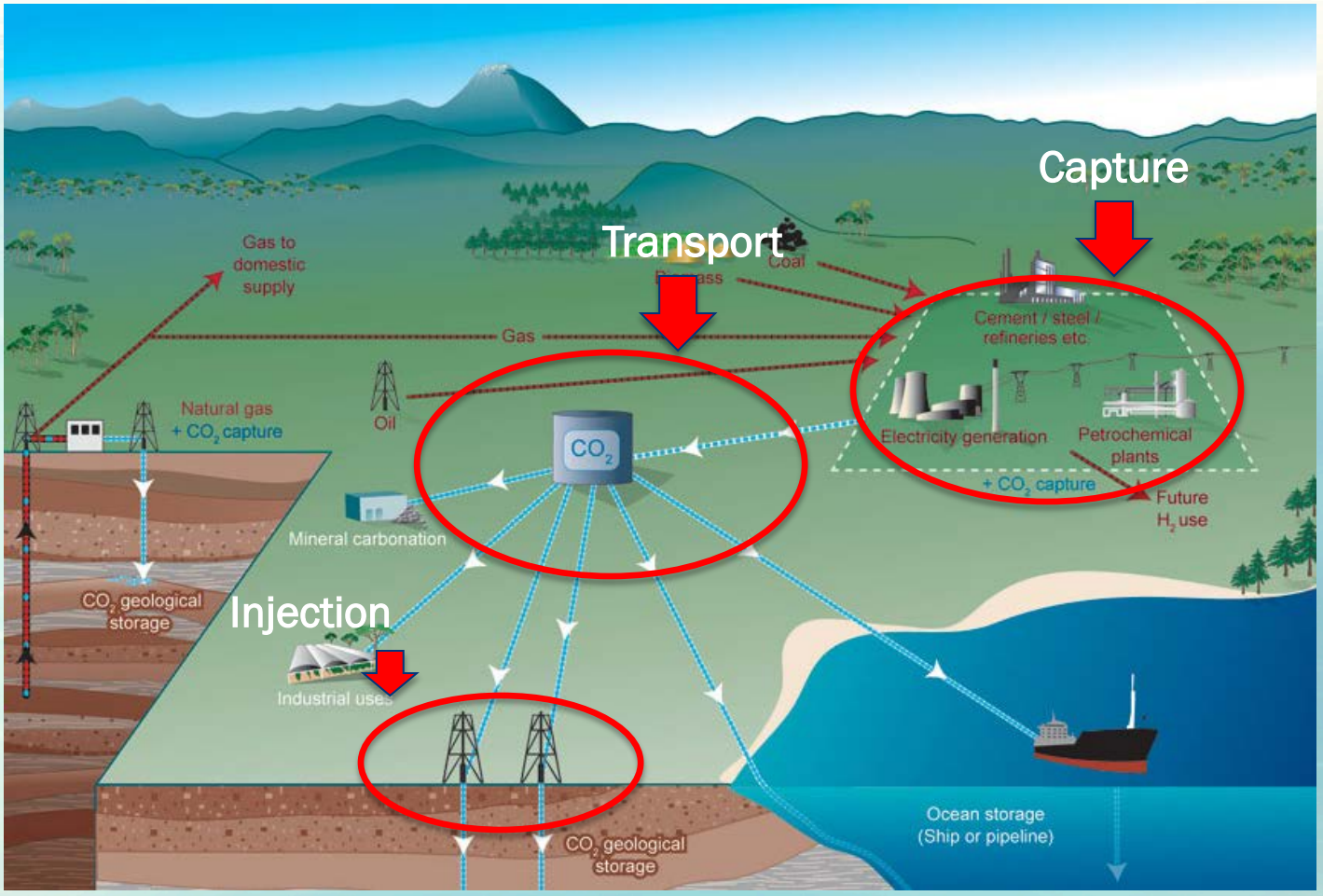
California's Climate Leadership



Potential Role of CCS

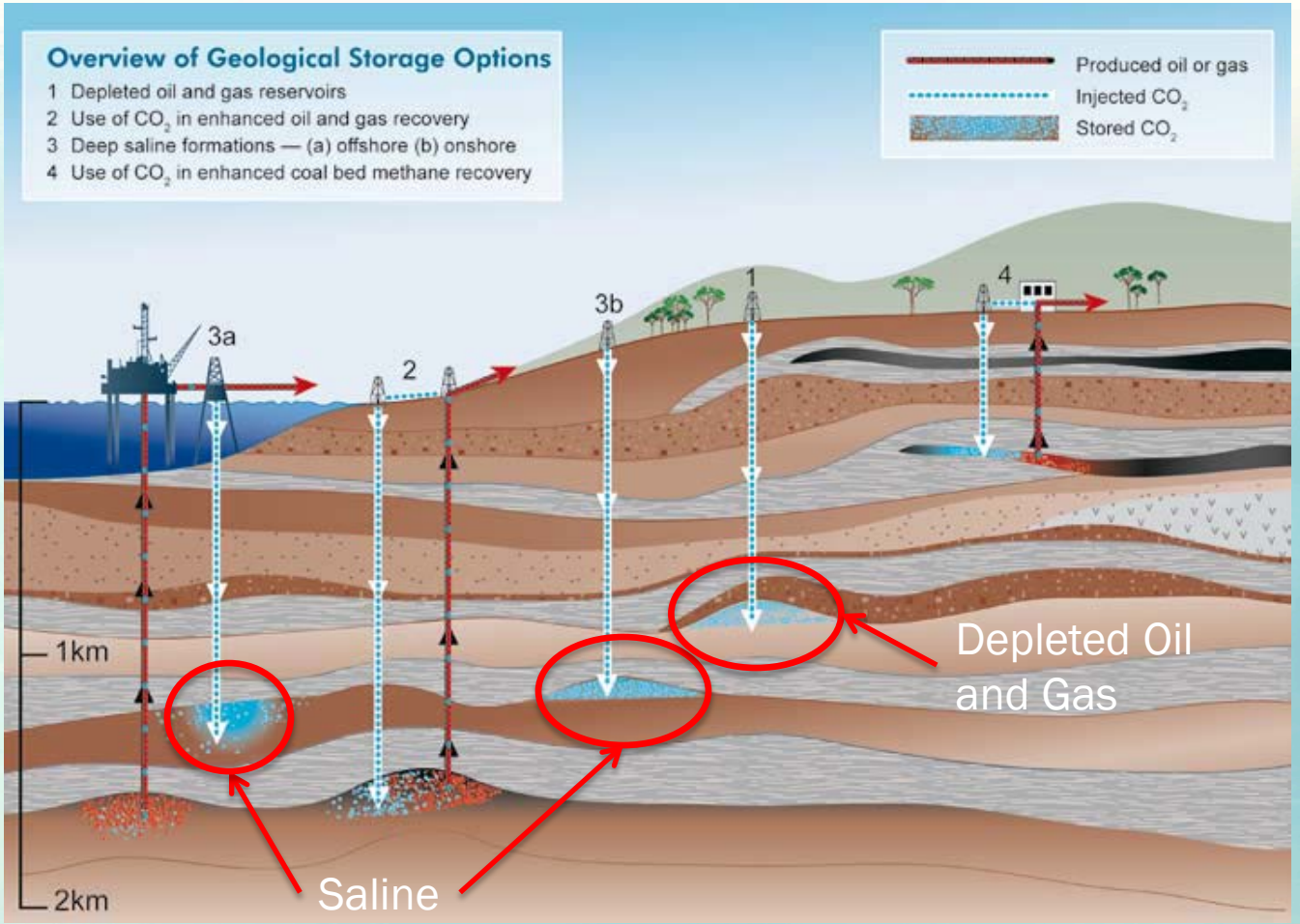
- California Council on Science and Technology found almost all solutions to 2050 goal require CCS
  - Consistent with IPCC studies for other regions
  - International Energy Agency emphasizes CCS not optional in meeting Paris climate agreement
  - Net negative carbon emission opportunities if combined with bioenergy

Carbon Capture & Sequestration (CCS) or Utilization



Source: CO_2CRC

CO_2 Geologic Sequestration Options



Source: CO_2CRC

Potential for CCS in California

- CO_2 storage potential in CA
  - 30–420 Gigatonne onshore formation capacity (California Geological Survey, 2011)
  - Offshore sub-seabed offers additional capacity
- Potential use in California's climate programs
  - Standalone strategy (e.g. refineries)
  - Compliance tool for market programs and standards:
    - Low Carbon Fuel Standard
    - Cap-and-Trade Program
    - Emission Performance Standard for Power Plants

Potential Sectors for Applying CCS

- Fuel production – focus for today
  - Ethanol plants
  - Refineries
  - Gas processing
  - Hydrogen production
- Electricity generation
- Cement
- Other large stationary CO_2 sources
- Costs vary by source
  - The purer the CO_2 stream, the less expensive
  - Fuel production, including H_2 production, tends to have less expensive options amenable to near term projects.

Lessons Learned from Underground Natural Gas Storage Leaks

- Site selection is key
- Well integrity requirements need to be strong
- Rigorous monitoring is necessary
- Best practices need to be followed. DOE's National Energy Technology Lab's best practice manuals:
  - Site Characterization
  - Geologic Storage Formation Classification
  - Monitoring, Verification and Accounting
  - Simulation and Risk Assessment
  - Carbon Storage Systems and Well Management Activities
  - Public Outreach and Education

Design Principles for CCS Program

- Protection of public health and the environment
- Robust GHG monitoring, reporting, and verification to ensure reductions are:
  - Real, permanent, quantifiable, and enforceable
- Focus on leak prevention
- Based on sound science
- Inclusion of expert state and federal agencies
- Transparent public process
- Serve as a model for other jurisdictions

RECENT CCS ACTIVITIES

Workshop and Board Update

- February 2016 workshop:
  - Presented initial staff thinking
  - Laid out timeline and basic framework
- December 2016 Board Update:
  - Updated Board on staff thinking
  - Presented idea of QM and permanence protocol
  - Board supportive of CCS

Technical Discussions

- Six technical discussions in 2016:
  - Accounting protocol
  - Well integrity
  - Monitoring
  - CO_2 Enhanced Oil Recovery
  - Site selection
  - Health and environmental risks, and environmental justice
- Literature review on these topics plus technology, economics, & upcoming projects

Staff Site Visits

- Ethanol plant (w/ & w/o CCS)
- Refinery
- Natural gas power plant (w/ & w/o Capture)
- Coal power plant w/CCS
- Oil field w/CO_2-EOR
- Natural gas storage field

Stakeholder Feedback

- Coalition of industry and NGOs sent letters in support of moving forward with CCS QM
- NGOs expressed support for CCS, in the context of strong permanence requirements
- EJ voiced opposition to CO_2-EOR in general, opposed to CCS in any current form

OVERVIEW OF CCS CONCEPT

CCS Protocol

- Single document with multiple parts:
  - QM with LCFS specific accounting
  - QM with Cap-and-Trade specific accounting
  - Permanence protocol with same permanence provisions for LCFS and Cap-and-Trade
- QMs exempt from Administrative Procedure Act
- Permanence protocol subject to complete regulatory development process
- Full Protocol will be subject to Board approval

ARB's Regulatory Adoption Process

Informal Development Process

- Public Workshops & Discussions
- Outreach
- Draft Proposals

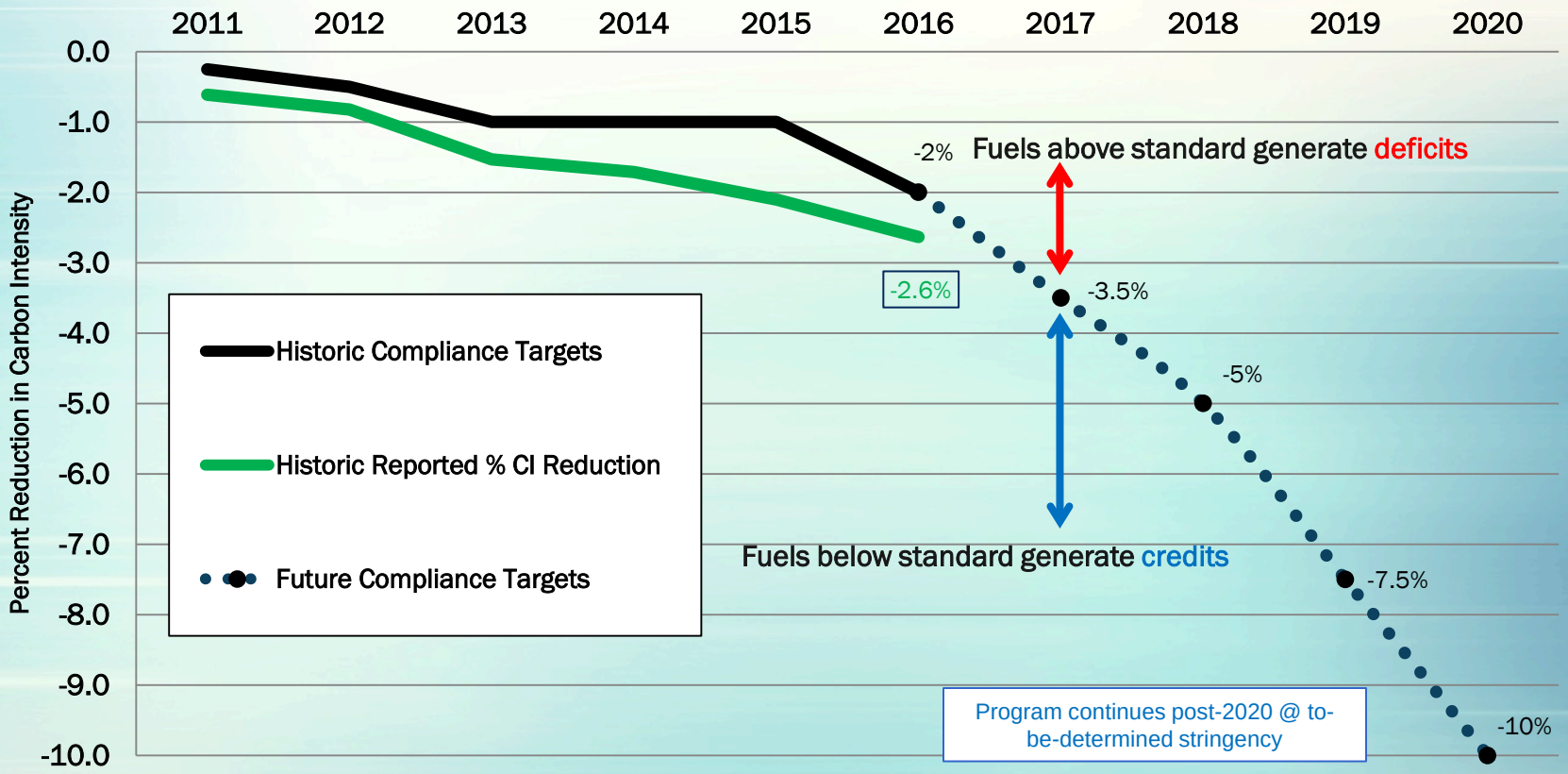
Formal Rulemaking Process

- 45-day Public Notice
- Board Hearing(s)
- Response to Comments
- OAL to Publish Regulation

LCFS Background

- Established in 2009; Re-adopted in 2015 due to legal challenge
- **Fuel Neutral** - Promotes all low carbon fuels
- **Life Cycle Accounting** - Ranks fuels with Carbon Intensity (CI) scores according to the greenhouse gas emissions resulting from each fuel's production and consumption
- **Flexible** - Regulated parties can comply by:
  - Innovating to reduce the CI of their fuels
  - Buying lower-CI fuels from other producers, or
  - Trading credits

How Does LCFS Work?



CCS in LCFS

- Credits go to capture facility
- Current proposal: storage facility must be co-applicant
- Capture and storage facilities do not need to be co-located
- Three avenues for credit generation:
  - Fuel producers undergo method 2 pathway for CI score
  - Innovative crude production yields credits pro-rated on crude coming to CA
  - Refinery investment yields credits to refinery

CCS & Cap-and-Trade Program

- Focus of this workshop is on LCFS, however must consider coordination and cohesion with Cap-and-Trade Program
- Scope of Cap-and-Trade Program is different from LCFS, but permanence requirements largely the same
- Develop a QM that could be incorporated into Cap-and-Trade Regulation at a later date as appropriate

PERMANENCE PROTOCOL

Permanence Protocol

- Required to comply with permanence protocol
- No credits issued until site specific permanence protocol is approved

Areas of Focus

- Risk-based site analysis
- Injection or production well material and structural integrity
- Operating requirements
- Monitoring, reporting, and verification

Risk-Based Site Analysis: US EPA Compatibility

- Compatible with Class VI:
  - ARB staff to approve or disapprove of specific projects
- Class II alone not sufficient to meet standards:
  - Well construction, monitoring, post-injection period more stringent with permanence protocol
  - Some current practices incompatible (e.g. blowdown and CO_2 transfer to other fields)

Risk-Based Site Analysis: Analysis Options

- Two overall analysis options
  - Prescriptive analysis and simpler process for sites with clearly low risk
  - Site-specific analysis for more complex sites where risk may be low but is not as clear
- Analyses meant to focus primarily on geology, well condition

Risk-Based Site Analysis: General Requirements

- Require primary injection zone with confining layer (seal)
- Secondary containment reservoir with confining layer to allow pressure dissipation
- Pressure dissipation interval with confining layer below injection zone to protect against seismicity in saline reservoirs
- Consider proximity to populations

Risk-Based Site Analysis: Area of Review

- Require computational fluid dynamic modeling for determination of AOR for all project types
- CO_2 plume (and/or pressure front) modeling may be required for AOR determination due to focus on atmospheric leakage
- No faults or fractures that are capable of transmitting CO_2 are allowed in AOR
- Remediation of all legacy wells in AOR

Well Material and Integrity: Cementing

- May require specific cement composition
- Specify locations along well to be cemented, (e.g. all production and injection wells cemented to surface)
- Injection zones required to use CO_2-resistant materials (e.g. CO_2-resistant cement or sheaths) for injection wells
- Cement evaluation logging required

Leak Mitigation Plan

- To avoid leaks and mitigate unforeseen leaks
- Plan to be updated periodically based on operational data
- Include possible leak pathways and plan for investigation, confirmation, quantification, and remediation

Operating Requirements

- Pressure management or other requirements to ensure confining layer integrity
- CO_2 purity requirements or other requirements to ensure continued well integrity
- Requirements on conditions that would prompt injection cessation
- Other requirements as needed

Monitoring, Reporting, and Verification: Pre-Injection and Injection Monitoring

- Pre-injection period monitoring to examine possible baseline conditions
- Injection period monitoring:
  - Wellhead and flow monitoring to quantify CO_2 injected
  - Continuous pressure monitoring at injection, production, and monitoring wells
  - Subsurface monitoring to track CO_2 movement
  - Surface monitoring to detect and quantify leaks if subsurface monitoring suggests surface leakage

Monitoring, Reporting, and Verification: Post-injection Monitoring

- Potential to align with U.S. EPA requirement and require 50 years post-injection monitoring
- Potential to align with Cap-and-Trade Program monitoring requirement for sequestration of at least 100 years
- Shorter timeframe possible under U.S. EPA requirements for CCS projects if metrics show permanent sequestration (e.g. plume stability)
- Require both operators and pore space owners to commit to permanence of CO_2 sequestration

Monitoring, Reporting, and Verification: Monitoring Plan

- Plan based on risk analysis
- Design principle of no atmospheric leaks
- Comparable to current Class VI monitoring plans
- Monitoring requirements technology neutral with specifications for leak detection and quantification requirements
- Periodic review and update required

Monitoring, Reporting, and Verification: Reporting and Verification

- Reporting and verification should align with MRR requirements
- Verification:
  - Third-party independent review of submitted material required prior to submission, submit review along with MRV materials
  - Includes site analysis, well-integrity, monitoring plan, and any updates

QUANTIFICATION METHODOLOGY

ARB's Quantification Methodology

- Initial focus on geologic sequestration
  - Saline reservoirs
  - Depleted oil and gas reservoirs
  - CO_2- enhanced oil recovery
- Potential future efforts include:
  - Conversion to building products (e.g., cement, plastics)
  - Conversion to fuels
  - Direct CO_2 capture from air and conversion to useful products

QM Areas of Focus

- Eligible activities
- CCS project system boundary
- Project emissions accounting
- Reservoir type specific considerations

Eligible Activity Examples

- Fuel production:
  - Ethanol with CCS (fermentation CO_2)
  - Biomethane (CO_2 separated from biogas)
- Innovative crude:
  - Crude oil upgrading: steam methane reformer
  - Co-gen or other oilfield units
- Refinery Investment:
  - Steam methane reformers
  - Burners, co-gen, other CO_2 sources

CCS Project System Boundary

- System boundary begins with capture, ends with injection (includes compression, recycling, and transport)
- For pathway analysis under LCFS, CCS QM will be an add-on to current analysis

Project Emission Accounting

- Only sequestered CO_2 is considered for adjusted CI or credits, sequestration of other pollutants (e.g. methane) would not count
- Account for intentional and unintentional emissions
- CO_2 recovered or produced and not re-injected (fugitive or off-site transfer) considered emitted
- Must have approved permanence protocol and show continued conformance

Reservoir Types

- Saline reservoirs, depleted oil reservoirs:
  - Injected CO_2 is assumed sequestered if approved by permanence protocol
  - Injection equipment emissions included
  - Account for emissions from brine or other fluid produced for pressure management or other purposes, if any

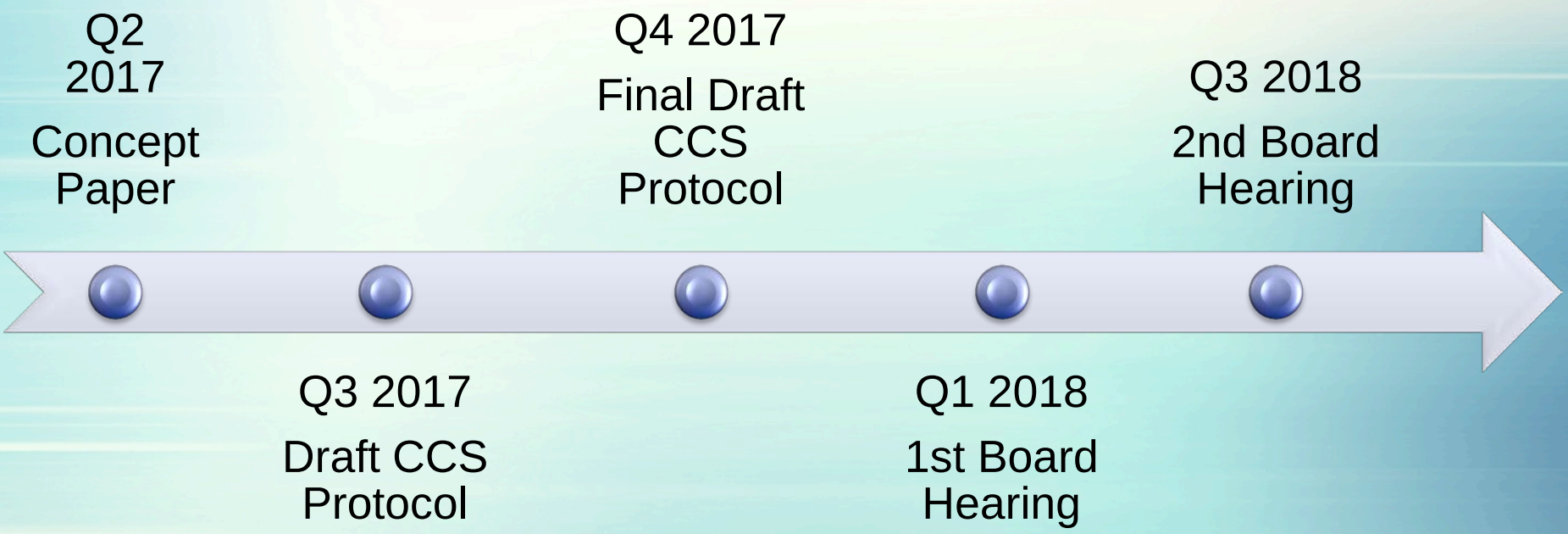
Reservoir Types

- CO_2-EOR:
  - Account for both injected and produced CO_2
  - CO_2 not re-injected considered emitted
  - Emissions from CO_2 processing at oil field allocated to LCFS credit generator, some process emissions may be allocated to oil field (e.g. normal oil extraction processes such as water separation and injection)

NEXT STEPS

Timeline

- CCS protocol development



Longer-term Activities

- Explore which forms of CCS could contribute the most to mid- or long- term goals
  - e.g. CCS in power, direct air capture, etc.
- Explore additional actions:
  - Targeted mid-term adoption strategies
  - Enabling potentially high impact technologies (e.g. direct air capture)
- Investigate potential CCS direct measures
- Consider incorporating CO_2 utilization into CCS protocol

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http://www.arb.ca.gov/cc/ccs/ccs.htm

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COMMENTS AND DISCUSSION