4-6 October, Nationals Park, Washington DC

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Life Cycle Assessment (LCA) of Activities in Project Controls: Megaprojects

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Outline

- Introduction
  - Project controls and sustainability
  - Carbon Emissions
  - Megaprojects
  - CPM Schedule
  - Research Gap, goals
- Methods
  - Project
  - Construction Schedule
  - Materials
- Results and Discussions
- Conclusions

Introduction – Megaprojects

- Large-scale complex ventures
- Cost $500 million – $1 billion USD
- Enormous cost and resources
- Span for long durations
- Legal and regulatory dependencies
- Institutional approach of project management
  - Government agenda
  - Legislations
  - Taxpayer funds

Portal North Bridge Replacement ($1.5 billion USD)
(Amtrak.com)

Introduction – Megaprojects

East Side Access Tunnel project ($11.1 billion USD) (WSJ 2016)

Hudson Yards Development ($20 billion USD) (hydc.com)

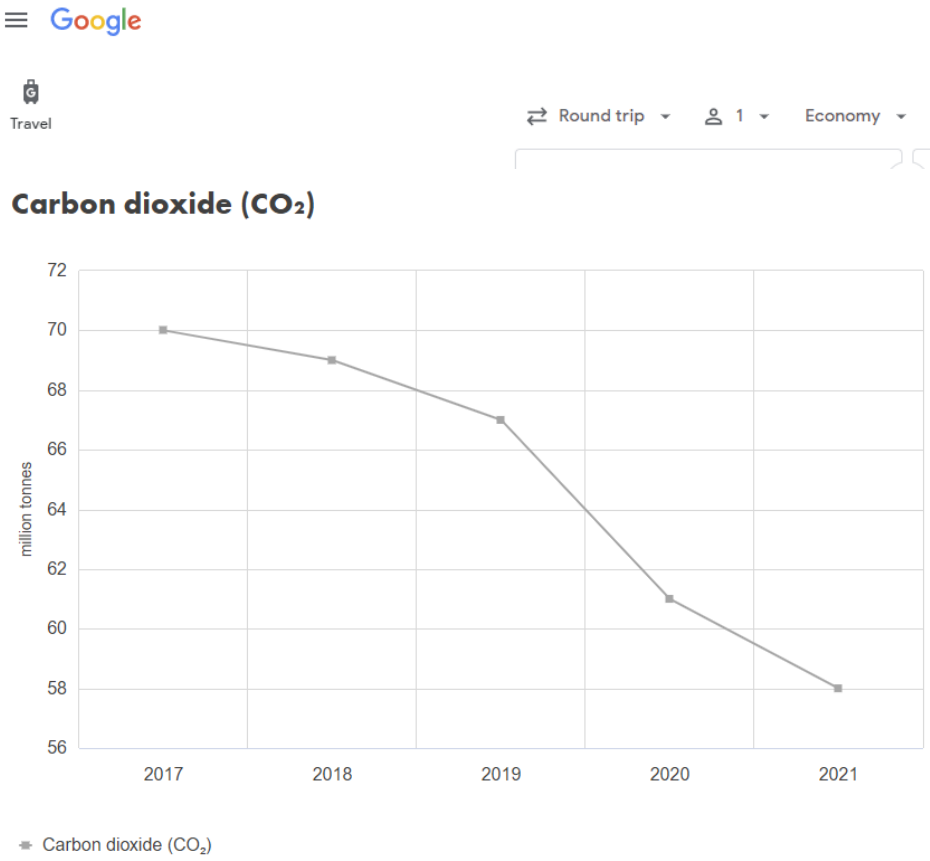
- Public opinion
- Political will
- Key legislations
- Delays and cost overruns
  - Technical challenges
  - Litigations

- Inflation Reduction Act, 2022
- United Nations Climate Change Conference (COP 26), 2021
- Communique by American Society of Civil Engineers

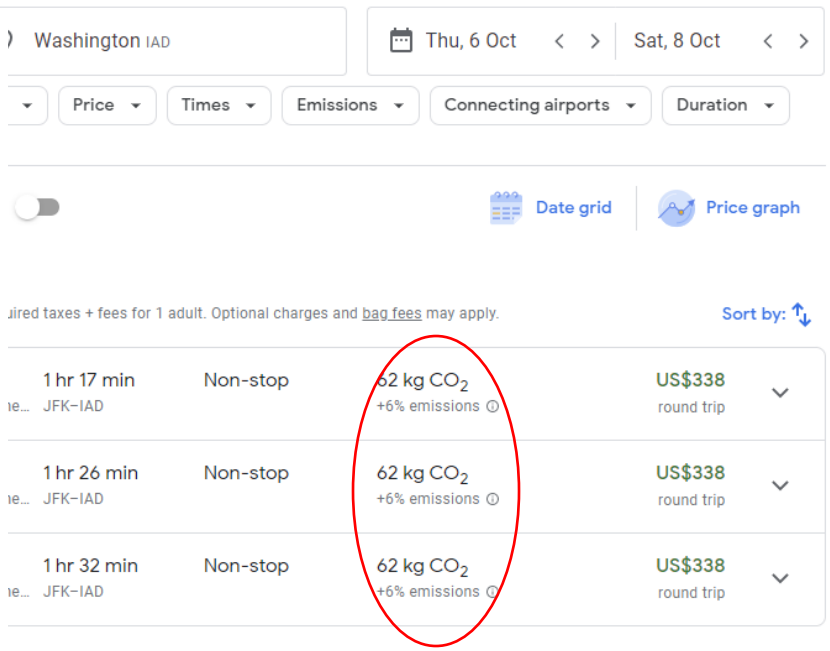
California High Speed Rail ($77 billion USD) (hsr.ca.gov)

Introduction – Carbon Emissions

- Construction Industry – 38% of global CO_2 emissions (UNEP)
- Cement, steel, glass – 11% of global CO_2 emissions (IEA)
- Cement – 5-8% of global CO_2 emissions (Mikulči´c et al. 2016)
- Vital monitoring of CO_2 emissions in construction projects
- Quantification is key to mitigation



CO_2 emissions over the years (Shell.com)



Google flights

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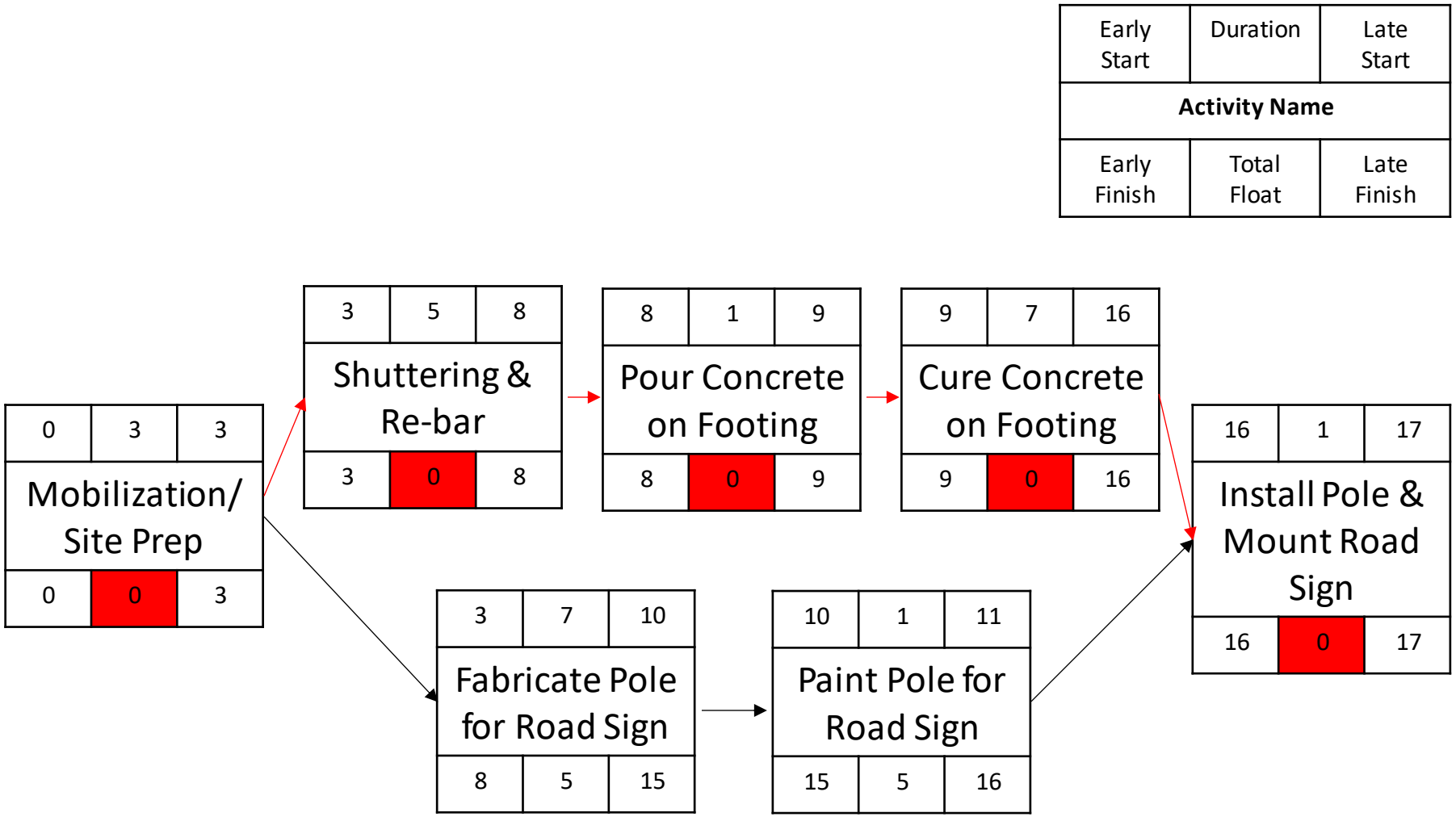
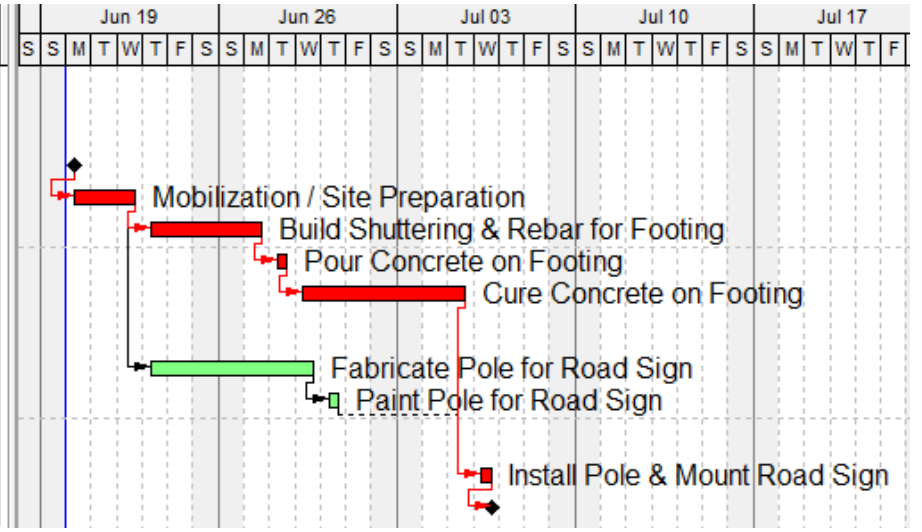
Introduction – CPM Schedule

- **Critical Path Method (CPM)**
  - Network diagram-based schedule model
  - Forward and backward pass
  - Activities
  - Milestones
  - Relationships
  - Durations
  - Planned dates
  - Resources
  - Cost

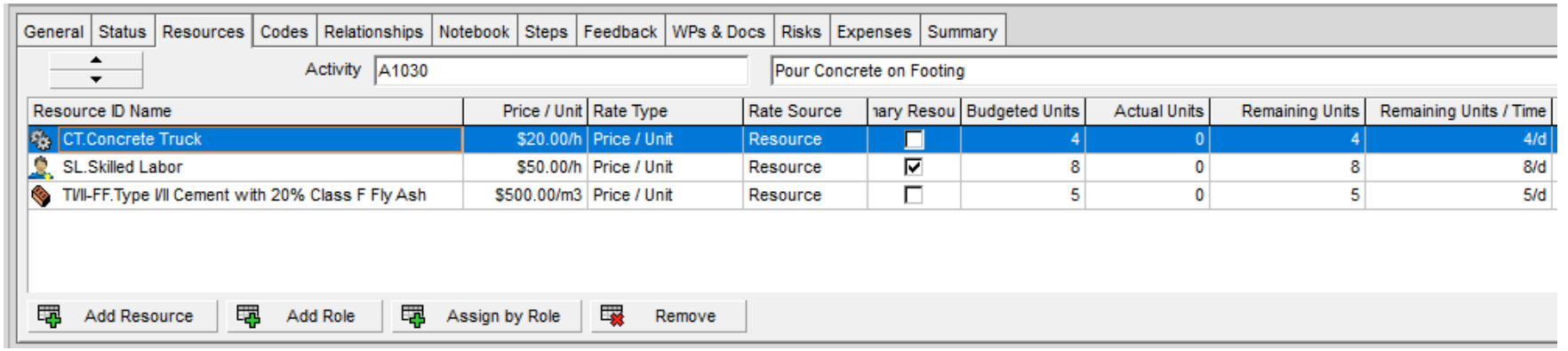


Introduction – CPM Schedule

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float	Primary Resource	Budgeted Total Cost
Road Sign F	roject - Example for Presentation	17	Jun.20.2022	Jul.6.2022	0		$15,900.00
Construction		16	Jun.20.2022	Jul.5.2022	0		$8,780.00
A1000	Start of Construction	0	Jun.20.2022		0		$0.00
A1010	Mobilization / Site Preparation	3	Jun.20.2022	Jun.22.2022	0	SL.Skilled Labor	$1,920.00
A1020	Build Shuttering & Rebar for Footing	5	Jun.23.2022	Jun.27.2022	0	UL.Unskilled Labor	$2,200.00
A1030	Pour Concrete on Footing	1	Jun.28.2022	Jun.28.2022	0	SL.Skilled Labor	$2,980.00
A1040	Cure Concrete on Footing	7	Jun.29.2022	Jul.5.2022	0	UL.Unskilled Labor	$1,680.00
Fabrication		8	Jun.23.2022	Jun.30.2022	5		$6,600.00
A1050	Fabricate Pole for Road Sign	7	Jun.23.2022	Jun.29.2022	5	WL.Welder	$6,360.00
A1060	Paint Pole for Road Sign	1	Jun.30.2022	Jun.30.2022	5	UL.Unskilled Labor	$240.00
Commissioning		1	Jul.6.2022	Jul.6.2022	0		$520.00
A1070	Install Pole & Mount Road Sign	1	Jul.6.2022	Jul.6.2022	0	SL.Skilled Labor	$520.00
A1080	Completion of Project	0		Jul.6.2022	0		$0.00



- **Project schedule – CPM**
  - Activities
  - Milestones
  - Relationships
  - Durations
  - Planned dates
  - Resources
  - Cost



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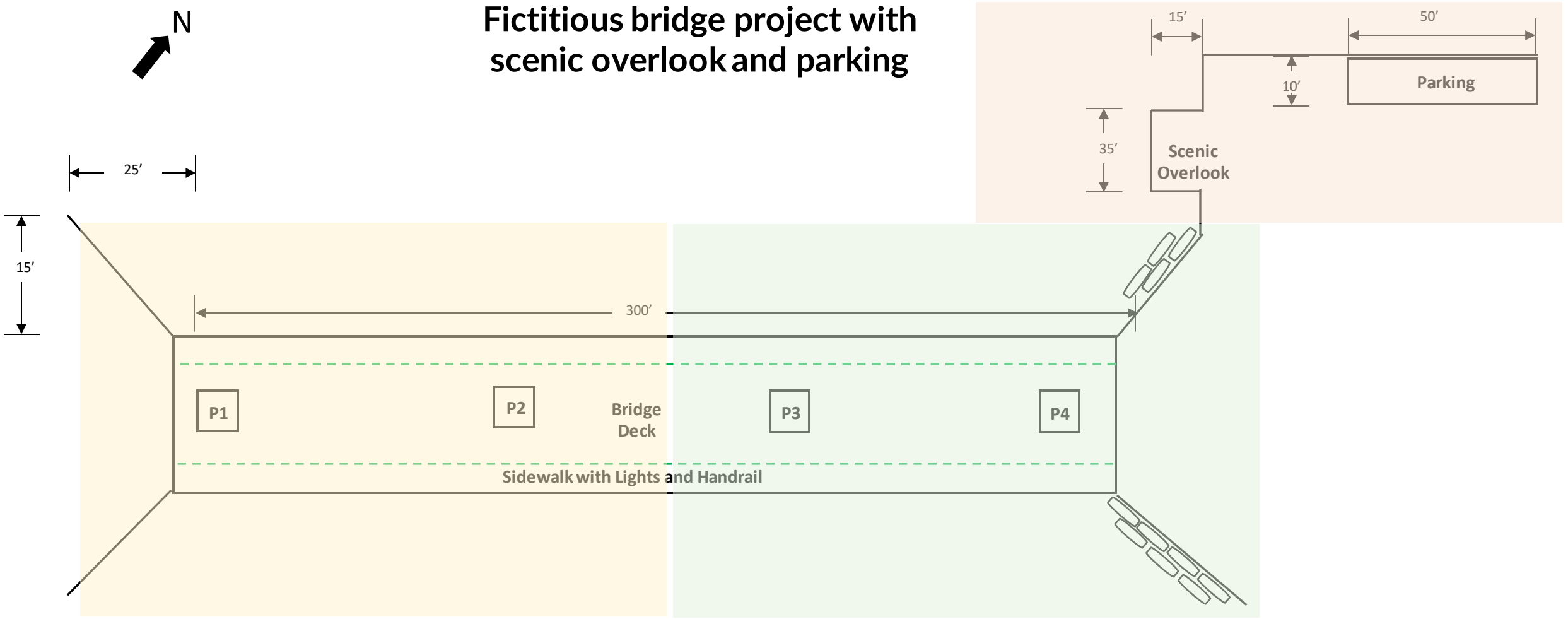
Introduction – Research Gap, Goal

- **Research Gap**
  - Lack of systematic monitoring of greenhouse gas emissions
  - Global Warming Potential (GWP)
  - Informed decision making
- **Objectives**
  - GWP for each activity
  - Material changes
  - Temporal changes of GWP
  - Cost and manhours

Fictitious bridge project with scenic overlook and parking



Phase I

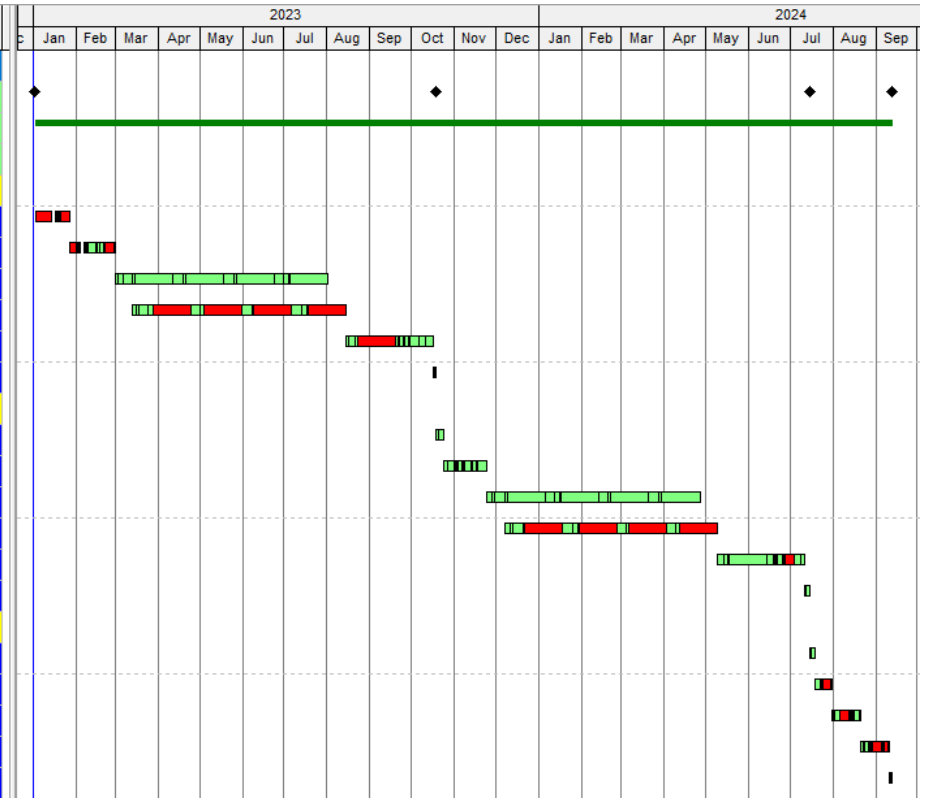
Phase II

Phase III

NOT TO SCALE

Construction Schedule

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
Fictitous Bridge with Scenic Overlook and Parking		444	1-1-23	9-12-24	0
Milestones		621	1-1-23	9-12-24	0
Level of Effort		444	1-2-23	9-12-24	0
Construction		444	1-2-23	9-12-24	0
Phase I: SW Section of Bridge with SW Approach		208	1-2-23	10-18-23	236
Mobilization and Site Preparation		19	1-2-23	1-26-23	0
SW Approach		23	1-27-23	2-28-23	402
Piles, Pile Cap, Pier and Pier Cap - P1		110	2-28-23	8-1-23	9
Piles, Pile Cap, Pier and Pier Cap - P2		110	3-13-23	8-14-23	0
Bridge Deck, Light Poles, Signage and Hand Rails		45	8-14-23	10-16-23	0
Miscellaneous		2	10-16-23	10-18-23	0
Phase II: NE Section of Bridge with NE Appraoch		193	10-18-23	7-15-24	43
Site Preparation		4	10-18-23	10-24-23	0
NE Approach		23	10-24-23	11-24-23	209
Piles, Pile Cap, Pier and Pier Cap - P3		110	11-24-23	4-26-24	9
Piles, Pile Cap, Pier and Pier Cap - P4		110	12-7-23	5-9-24	0
Bridge Deck, Light Poles, Signage and Hand Rails		45	5-9-24	7-11-24	0
Miscellaneous		2	7-11-24	7-15-24	0
Phase III: Scenic Overlook and Parking		43	7-15-24	9-12-24	0
Site Preparation		3	7-15-24	7-18-24	0
Strip Footings for Scenic Overlook		9	7-18-24	7-31-24	0
Concrete Deck, Lights, Signage and Handrails		14	7-31-24	8-20-24	0
Parking		15	8-20-24	9-10-24	2
Miscellaneous		2	9-10-24	9-12-24	0



Created by using Oracle Primavera P6 Professional 18
Overall Duration = 620 calendar days (1 year, 8.5 months)

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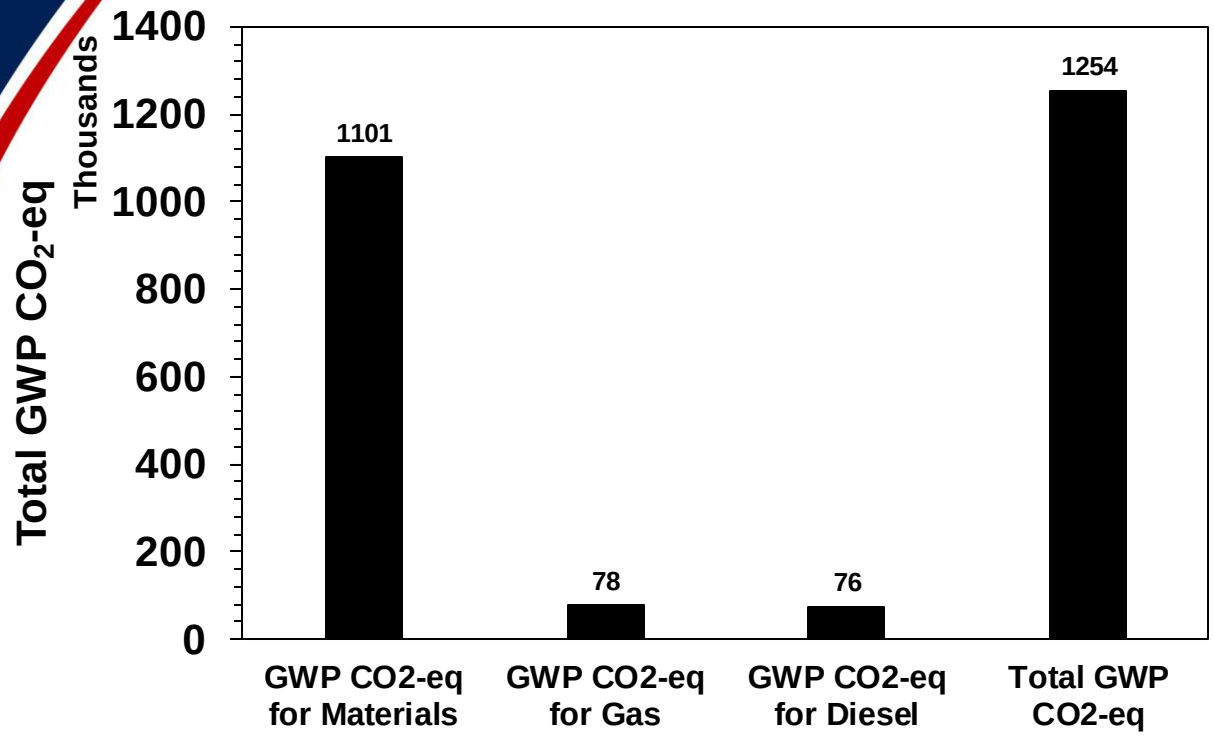
Materials

Code	Item	GWP CO_2-eq 100 / unit Material
Steel Rebar	Steel reinforcement	2.10
HG Steel	Hot-dipped Galvanized Steel	2.90
WP Steel	Welded Pipe Steel	2.81
TI-P	Concrete with Type I Cement (high C_3A+C_3S), no SCMs, smaller aggregate fraction	451.04
TI/II-P	Concrete with Type I/II Cement, no SCMs, smaller aggregate fraction	451.04
TI/II-FF	Concrete with Type I/II Cement, 20% replaced with Class F Fly Ash, smaller aggregate fraction	380.33
TI/II-FC	Concrete with Type I/II Cement, 30% replaced with Class C Fly Ash, smaller aggregate fraction	346.08
TI/II-P-2	Concrete with Type I/II Cement, no SCMs, larger aggregate fraction	444.92
TI-FC-2	Concrete with Type I Cement (high C_3A+C_3S), 30% replaced with Class C Fly Ash, larger aggregate fraction	342.16
TIL-FC-2	Concrete with Type IL Portland Limestone Cement, 30% replaced with Class C Fly Ash, larger aggregate fraction	313.68

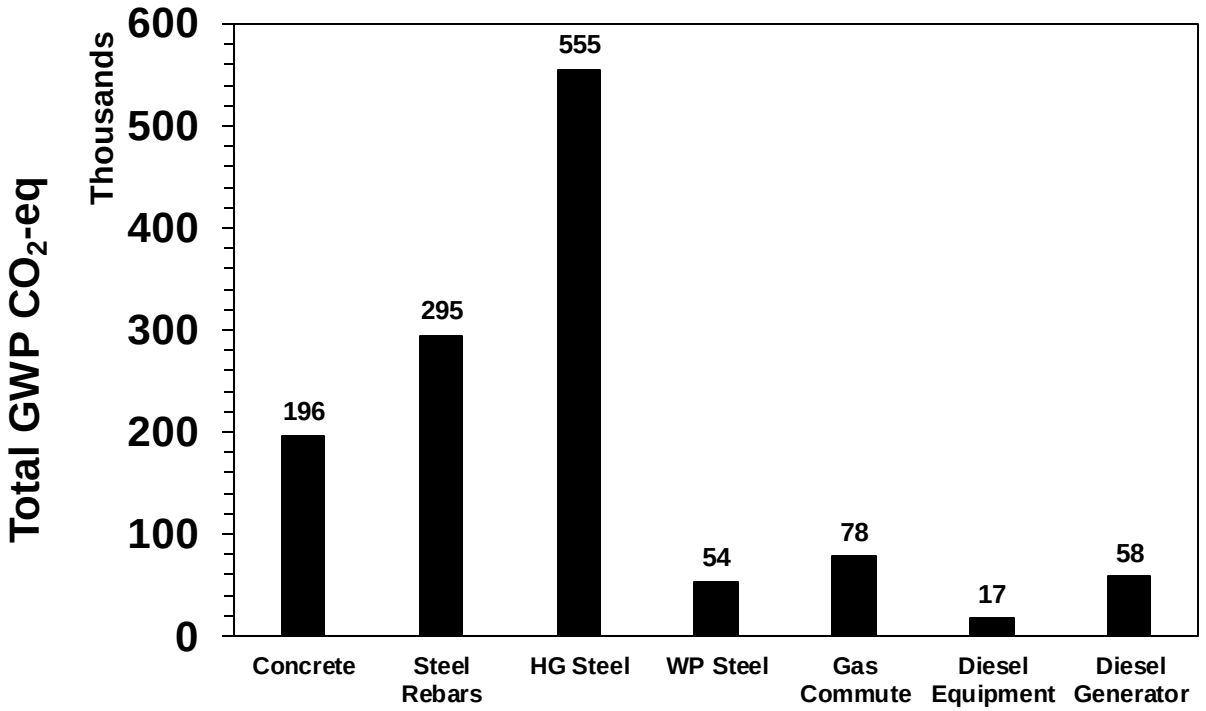
Life Cycle Assessment (LCA)

- **Cradle to Gate (ISO 14040)**
  - Scope and boundaries
  - Life Cycle Inventory (LCI)
  - Life Cycle Impact Assessment (LCIA)
  - Interpretation
- **Functional Unit**
  - Materials – m^3, kg
  - Fuel – L, hour
- **Tools**
  - Open LCA
  - Green Concrete LCA

Results and Discussions – Total GWP Emissions



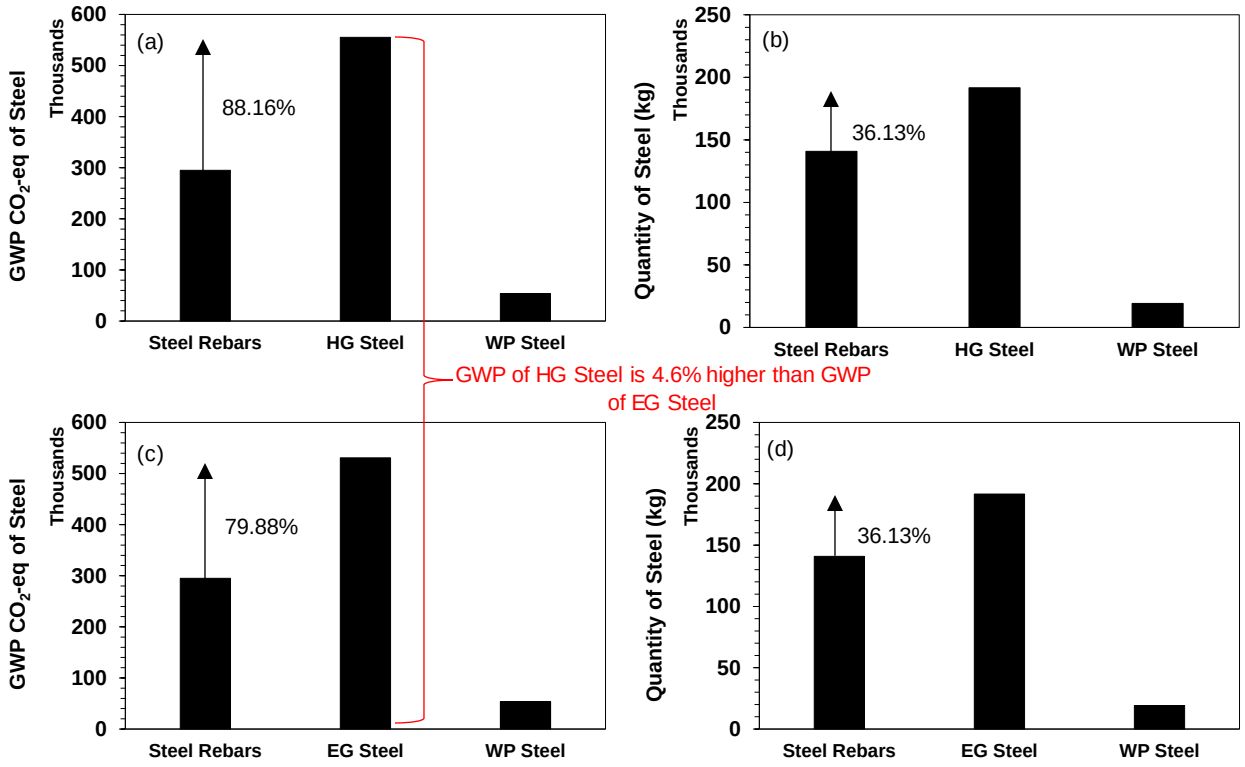
GWP emissions due to materials & fuel



Categories of emissions

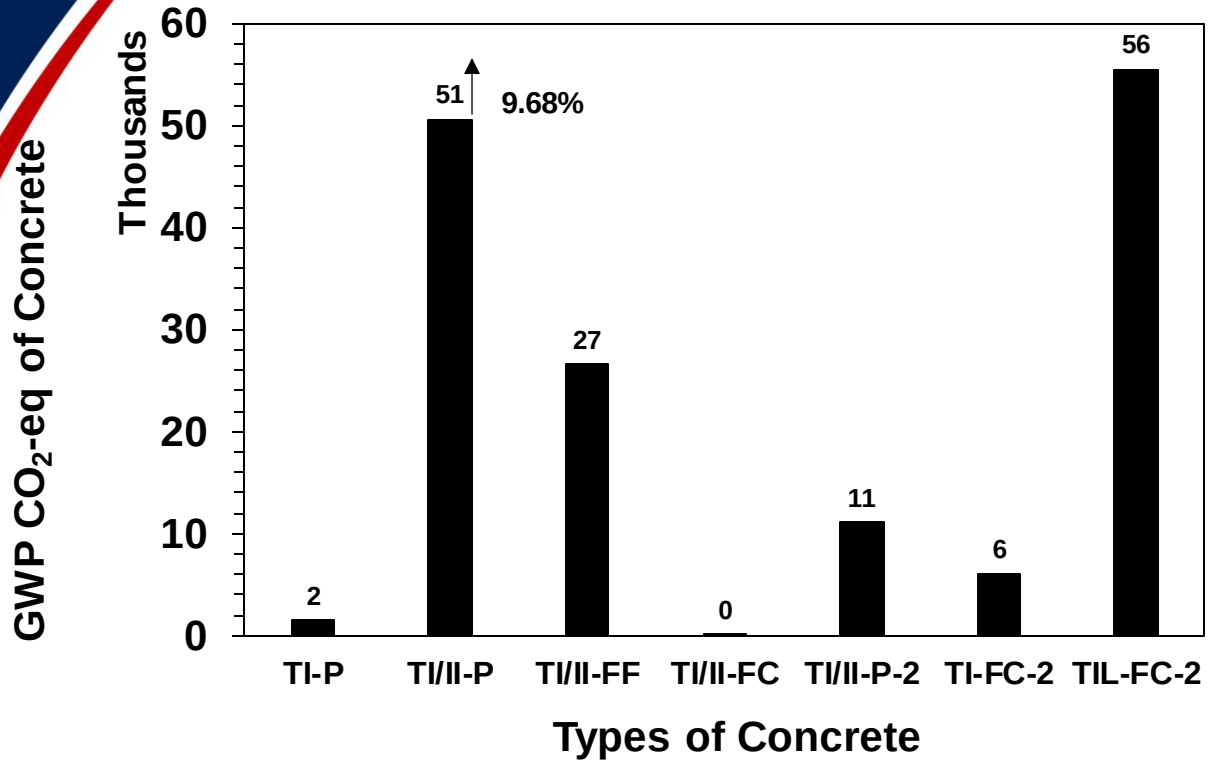
Results and Discussions - Steel

Example Scenario: Hot-dipped galvanized steel is replaced with equivalent weight of Electrogalvanized (EG) steel

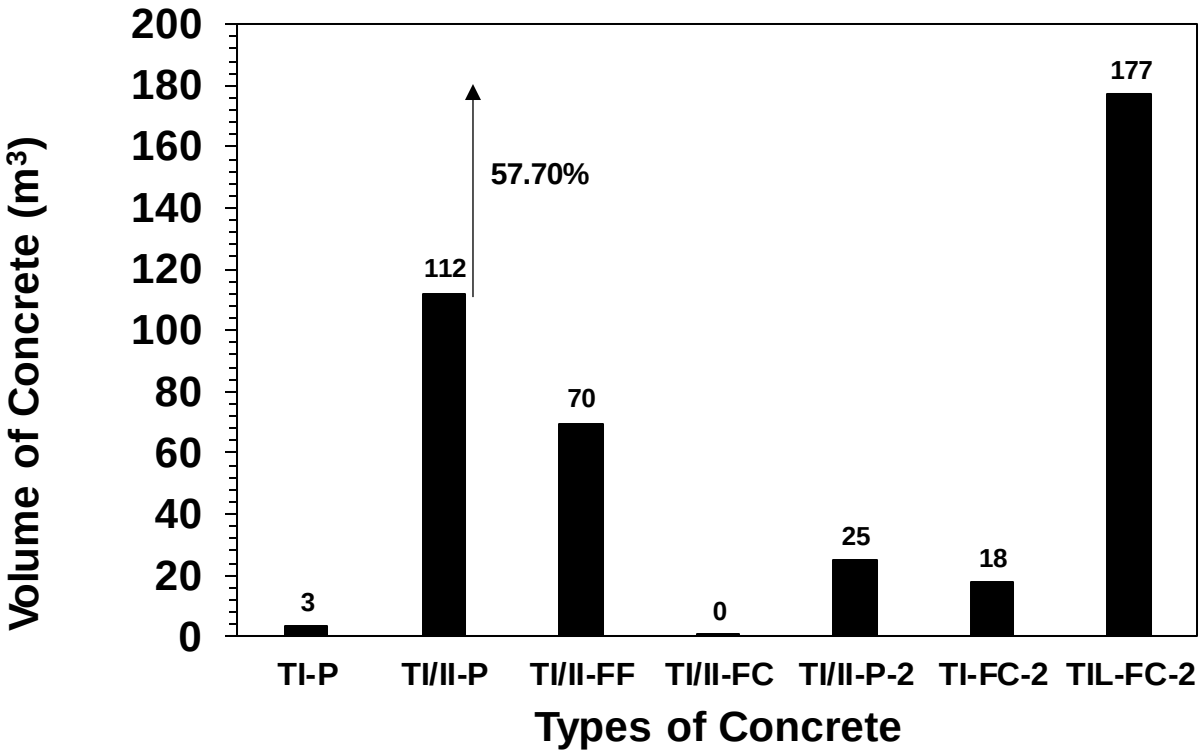


(a) GWP emissions due to steel categories, (b) Total quantities of steel used, (c) GWP emissions in example scenario, (d) Total quantities of steel in example scenario

Results and Discussions - Concrete

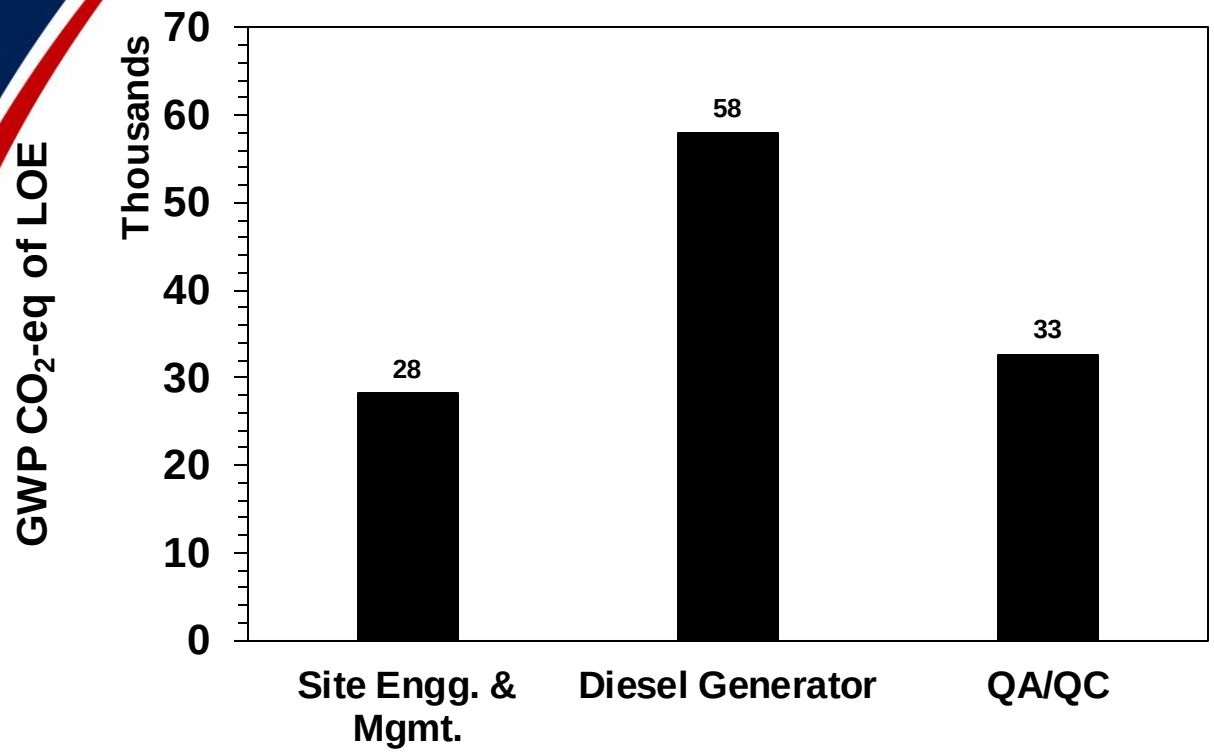


GWP emissions due to different types of concrete used

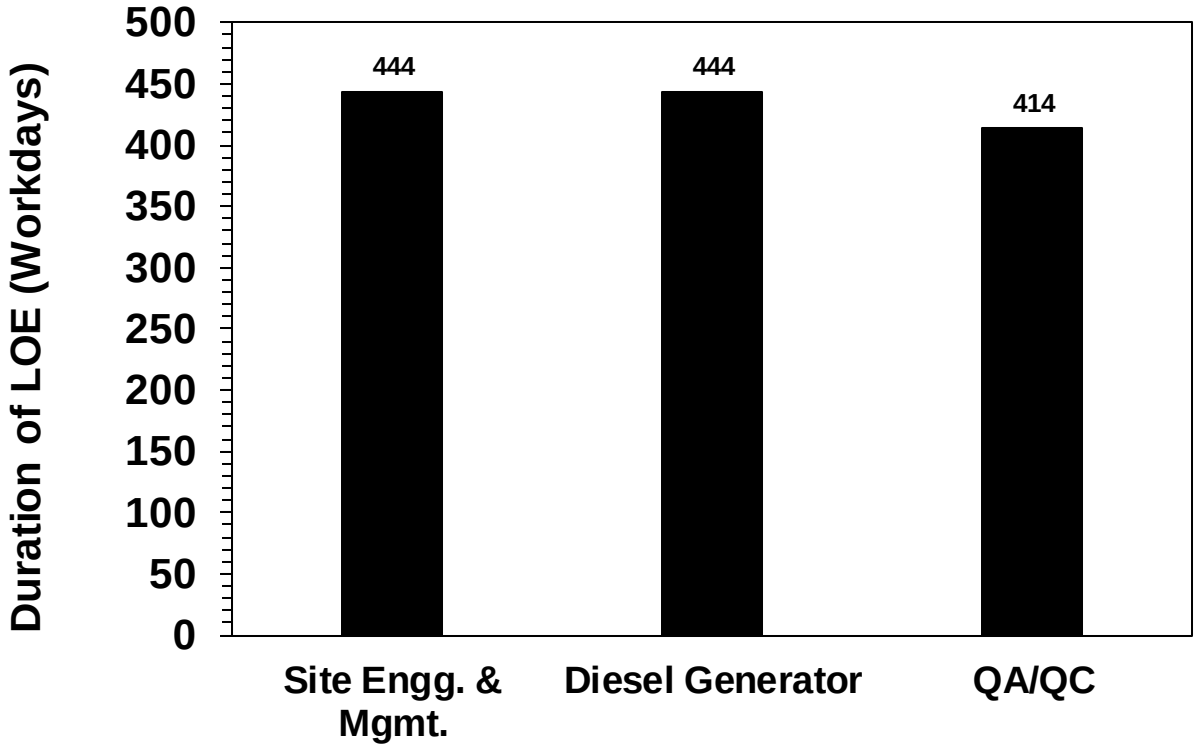


Volume of different types of concrete used

Results and Discussions - LOE



GWP emissions for LOE activities



Duration of LOE activities

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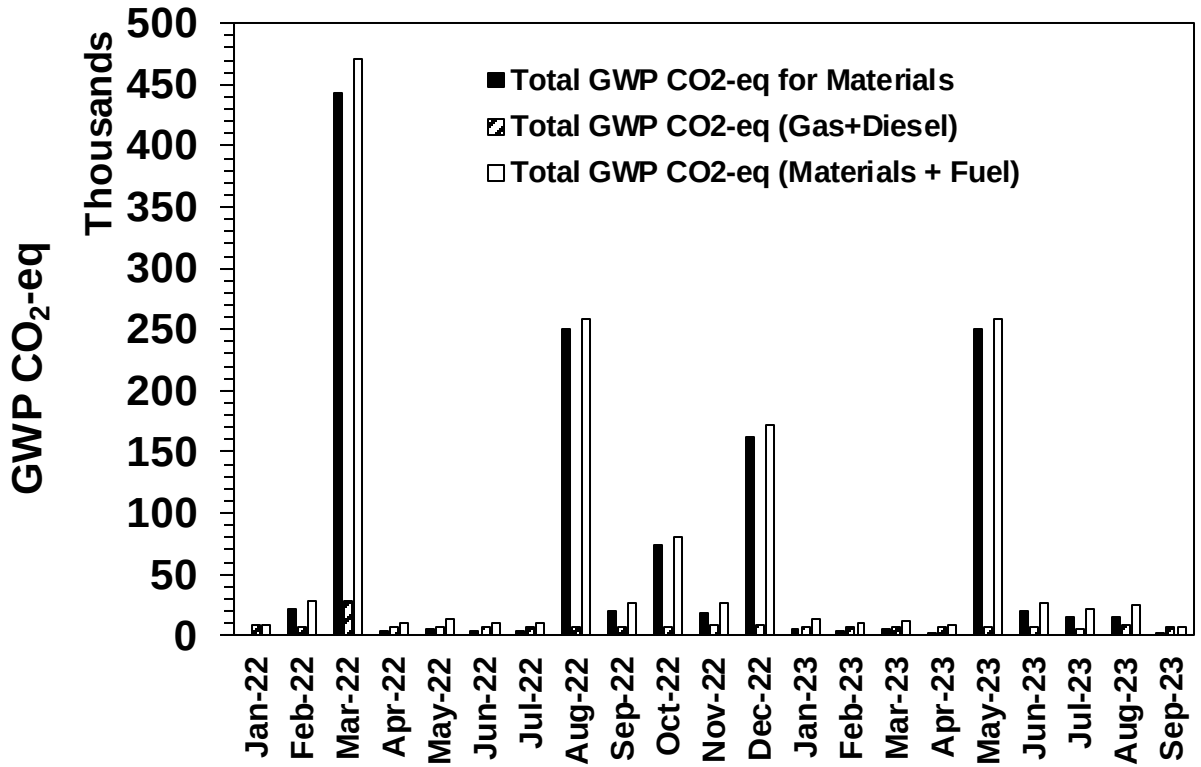
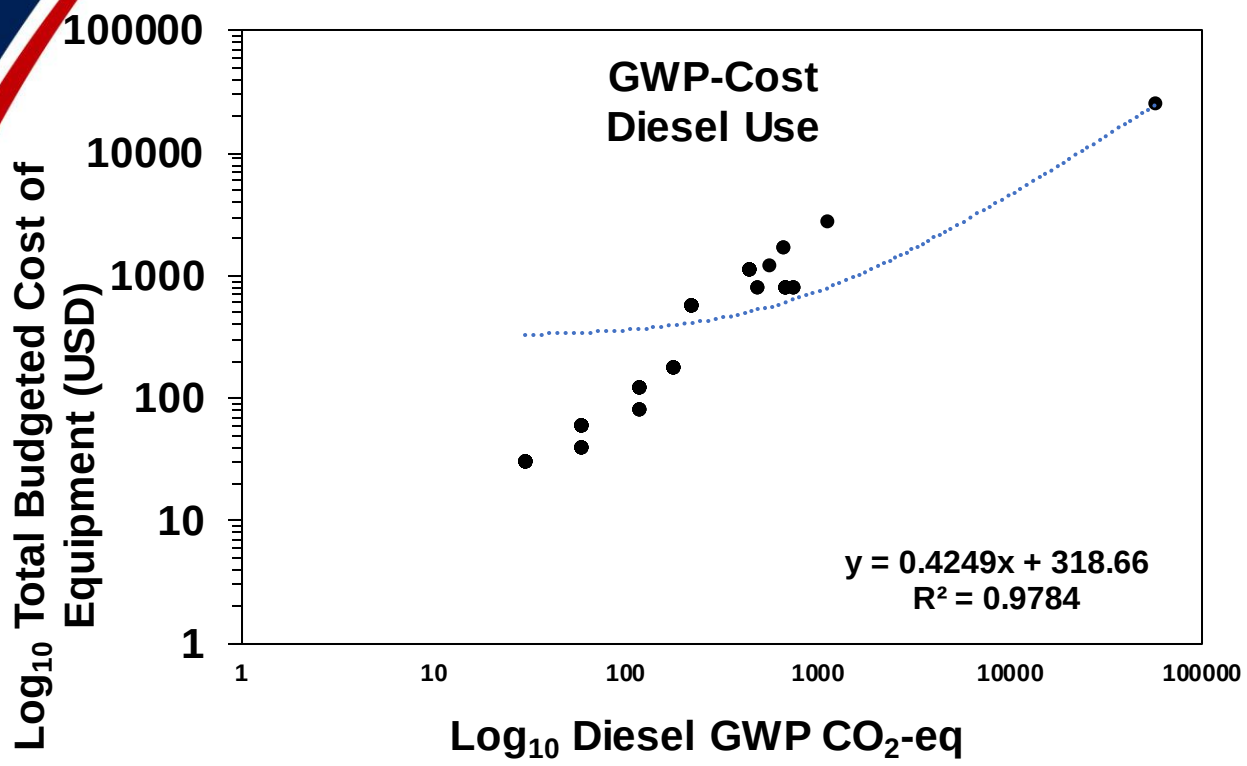
Results and Discussions – Temporal Analysis

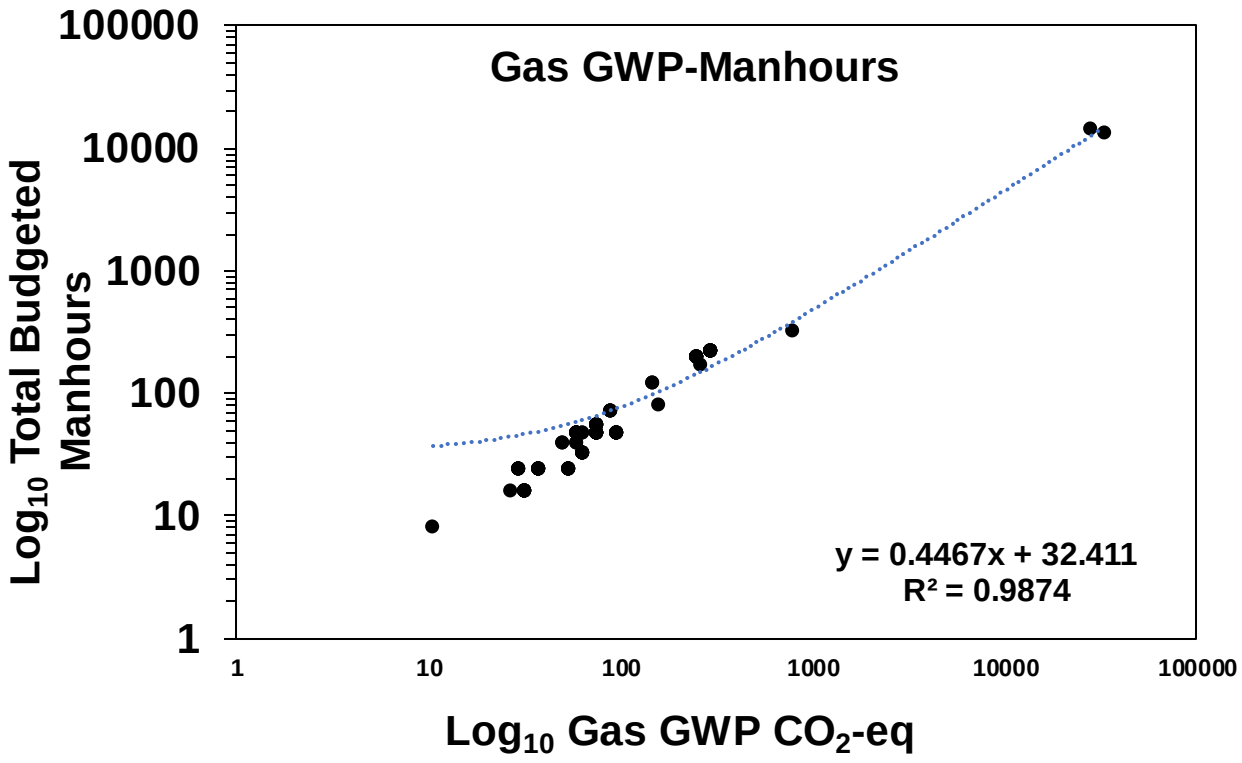


GWP emissions throughout the life cycle of the project

Results and Discussions – Cost and Manpower



Correlation between cost and GWP due to diesel use of equipment



Correlation between manhours and GWP due to gas use by personnel

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Key Conclusions - General

- New method of GWP quantification at an activity level
- $100\text{-}GWP_{Materials} > 100\text{-}GWP_{Fuel}$
- $100\text{-}GWP_{HG\ Steel}$ is highest among steel types
- Temporal analysis for effective decision making

Key Conclusions - Megaprojects

- Sequence of activities may have a tangible impact on megaprojects
- Small changes in GWP from alternative materials - big impact on megaprojects
- Public sector entities and environmental concerns

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THANK YOU

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