Objectives

- Set Context for Action (Adapt and Mitigate!)
- Convey Opportunity (Financial, Resilience, & Community Benefit)
- Align to Local Policy / Goals (100%RE, Resilience Hubs)
- Raise Risk of Non-action (future retrofit?)
- Share Examples (to build confidence)
- [Understand Psychology of Choice and Why People Won’t Act]
1. District Systems Infrastructure
An Approach for Affordable, Resilient, Healthy Communities

2. Flexible Adaptation Pathways
An Approach for Sea Level Rise and Flood Infrastructure

Cole Roberts, PE, LEED AP
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Jack Hogan, PE
Jack-W.Hogan@arup.com
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Reduction  Resilience
2C/3.6F

We don’t want to be here

Mitigation

Adaptation

2012

2050

2100

Atmospheric CO₂ e ppm

380

450
Early & Right Action
Recognize a problem
Choose to act to remedy or avoid the problem
Act effectively

Adapted from Collapse – How Societies Choose to Fail or Succeed, Jared Diamond
The Cost of Climate Change in Hawaii
Hawai‘i’s Future Liabilities are Expected to Cost $88 Billion
Action has been voluntary. That is changing.

“Failure to act in the face of climate risk could result in legal liability.

...prevailing practices... [and] explicit standards.... are not the only factors that determine legal responsibility for... failing to act reasonably in the face of ascertainable climate risk.

...obligations can be heightened when considerations of public health or safety are at issue.
District Systems Infrastructure
An Approach for Affordable, Resilient, Healthy Communities

Focus on Energy Systems in Dense Areas

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Effective Action – Climate Positive Community

1. Dense
2. Walkable
3. Efficient
4. On-site Renewable
5. Off-site Renewable
6. Trees + Travel
Density Enables Deep Improvements

35%
Density Enables Deep Improvements

Density
(FAR of 1x)

2x Density
(FAR of 2x)
Density Enables Deep Improvements

Density (FAR of 1x)

2x Density (FAR of 2x)
Land Use

District Systems

Buildings

Finance & Procurement

ARUP
O’ahu Resilience Strategy

“Driven by distance and isolation, islands have long been incubators of innovation, pioneers of self-sufficiency, and builders of social capital”

Action 7: Reduce utility costs
Action 15: Develop resilience hubs
Action 22: Expand district cooling
Action 32, 33, and many more
Developing high performance districts at scale which utilizes renewable, thermal and electrical technologies in order to...

- **Reduce utility costs** and **optimize performance for buildings and key infrastructure/operational systems**
- Help to achieve long term Hawaiian goals for **100% RE**, water/waste performance, and **new resilience hubs**.
- **Achieve regional environmental goals** including greenhouse gas emissions, habitat restoration, sea level rise mitigation and regional air & water quality improvements
VALUE: Place Based District Development Significantly Increases the Quality of Place While Minimizing Costs
VALUE: Place Based District Development Significantly Increases the Quality of Place While Minimizing Costs
VALUE: District Systems Return Space to Buildings, While Reducing Resource Consumption

<table>
<thead>
<tr>
<th></th>
<th>Carbon Savings</th>
<th>Water Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Up to 30%</td>
<td>Up to 90%</td>
</tr>
</tbody>
</table>

Space Requirements by CUP Strategy

- **Onsite Area Savings**
- **Carbon Savings**
- **Water Savings**

Approx. Area

- Distributed Building Systems
- District Four-Pipe System
- District Four-Pipe System + Geothermal
- District Two-Pipe System

Legend:
- Building Mechanical Room Area (sf)
- Building Roof Area (sf)
- CUP Building Area (sf)
- CUP Roof Area (sf)
- Add'l Infrastructure Area (sf)
ENERGY: There are Many Solutions and Each TOD Area is Unique
District Systems Have Proven Powerful as Attractive Showcases and Tourist Destinations

- Department of General Services, Sacramento, CA
- Hammarby-Sjostad, Sweden
- False Creek, Vancouver, Canada
- Stanford University, Palo Alto, CA
- University of Chicago, Chicago, IL
- University of Chicago, Chicago, IL
VALUE: Infrastructure Systems Can Optimize at a District Scale and Provide Additional Financial and Operational Benefits

1. Increased system efficiency
2. Greater control of sources & systems
3. Reduced carbon emissions
4. Reduced water consumption
5. Expandable to new projects & customers
6. Resource recovery potential
7. Reduced operating cost
8. Streamlined maintenance
9. More space in buildings for Googlers
LEADERSHIP: District-Scale is the New Norm, But Net-Zero and Islandable Systems are the New Frontier

- ~200 projects in recent years in the US and Canada
- Examples:
  - Atlanta Station
  - District Energy St. Paul
  - Fort Detrick
  - **Hawaii Seawater Air Conditioning**
  - Longwood Medical Area
  - NRG Energy Center Phoenix
  - Stanford University
  - University of Oklahoma

*Sourced from:*
- IDEA
- NCPPP
- IEA
- NRG Thermal
- Corix
- Chevron Energy Services
- Veolia Energy
- Macquarie Infrastructure
10.0 FTE

14 FTE’s

M$ 3.7/yr

+ Consolidated emissions with tighter controls
+ Building insurability benefit
+ Building occupant safety
+ More sophisticated controls

5.0 FTE’s

6.0 FTE’s

M$ 1.0/yr

ARUP
Energy Recovery

Potential for Ground Source Heat Exchange

Cooling

Heat Recovery Potential

Heating

Potential for Ground Source Heat Exchange
Saving Millions of Dollars per Year (Reducing Utility Costs)

Life cycle cost thermal comparison

Value Created
Self-Perform Case - Annual Cash Flow (US$)
P3 - Cash Flow (US$)

Cash outflows - Procurement & Pre-Operations
Cash outflows - Service payments
Tax (-) creditor / (+) debtor
Annual cash flow
CASE STUDY: Atlantic Station

Atlantic Station is unique because the $2B commercial redevelopment project was undertaken with the assumption that a district cooling system would be built concurrently.

KEY FIGURES

Procurement: Build-own-operate

Financing: $24M revenue bond, plus other funding sources
CASE STUDY: Honolulu SWAC

Honolulu Seawater Air Conditioning (SWAC) is a district cooling project planned to serve about 40 buildings in downtown Honolulu. The project is in the procurement phase, and expects to begin construction in 2020 with operations beginning in 2021.

KEY FIGURES

Procurement: Build-own-operate

Cost: $250 – 300M

Financing: $145M tax-exempt revenue bonds
$113M taxable revenue bonds
$47.8M private equity
Flexible Adaptation Pathways
An approach for Sea Level Rise and Flood Infrastructure

Focus on Iwilei-Kapalama

Jack Hogan, PE
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Objectives

- Describe Flexible Adaptation Pathways
- Demonstrate appropriateness for State TOD planning projects
- Highlight recommendations for implementation
Infrastructure Needs Assessment - Existing

**Infrastructure** | **Plans Outlined** | **Costs Estimated**
--- | --- | ---
Sewage | ✓ | ✓
Water | ✓ | ✓
Drainage | ✓ | ✓
Storm water quality | ✓ | ✓
Intersections and roadways | ✓ | ✓
Coastal flooding | ✗ | ✗

**Work in Progress:**

- East Kapolei
- Halawa Stadium
- Iwilei Kapalama
Infrastructure Needs Assessment – Future (Proposed)

Map: Hurricane inundation +1m SLR, NOAA/CSP and Dr. Kwok Fai Cheung (UH/SOEST)

(Proposed) Large scale flood infrastructure needs considered for TOD areas

(Proposed) Flexible Adaptation Pathways applicable to infrastructure evaluation and planning

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Plans Outlined</th>
<th>Costs Estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage</td>
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<td>✓</td>
</tr>
<tr>
<td>Water</td>
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<tr>
<td>Drainage</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Storm water quality</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Intersections and roadways</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Challenge

- Large scale infrastructure is *capital-intensive* and *long-lived*
- *Uncertainty* in how the future may unfold due *climate* and *socio-economic* conditions
Tidal flooding – 3ft SLR

Source: NOAA Digital Coast Sea Level Rise Viewer
Tidal flooding – 4ft SLR

Source: NOAA Digital Coast Sea Level Rise Viewer
Tidal flooding – 5ft SLR

Source: NOAA Digital Coast Sea Level Rise Viewer
Uncertainty – When and How Much?

Accumulated Sea Level Rise (feet) at Kapalama Canal
Response – Infrastructure Planning – Static Approach

- Static ‘optimal’ plan using a single ‘most likely’ future
- Static ‘robust’ plan that will produce acceptable outcomes in most plausible future worlds

(Bessai and Hulme, 2007; Dessai and Van der Sluijs, 2007; Hallegatte et al., 2012).
Response – Infrastructure Planning – Dynamic Approach

- Dynamic adaptive plans contain a strategic vision of the future, commit to short-term actions, and establish a framework to guide future actions

Rhine Delta, Netherlands

Delta Programme

Thames Estuary 2100, London, UK

UK Environment Agency

(Albrechts, 2004; de Neufville and Odoni, 2003; Haasnoot et al., 2011; Hallegatte, 2009; Hallegatte et al., 2012; Ranger et al., 2010; Schwartz and Trigeorgis, 2004; Swanson et al., 2010).
Flexible Adaptation Pathways – Concepts

- **Real options** – infrastructure options that are fitted with flexibility to adapt to future changes, rather than for a specific design scenario

- **Potential lock-ins** – when an option leads to a failure to adjust adequately to a changed environment; path-dependency of investment decisions can lead to stranded assets if conditions change

- **No regrets options** – options which achieve positive outcomes under all plausible projections of climate change

- **Trigger and Tipping points** - tipping point is the point at which a particular action is no longer adequate for meeting objectives; a trigger indicates when a decision is needed for a forthcoming action

- **Flexible adaptation pathway map** – path of actions that result in least regrets and achieves overall objectives

(Haasnoot et al. / Global Environmental Change 23 (2013) 485–498)
Iwilei-Kapalama

**Objective**: Ensure adequate infrastructure capacity and *flood protection* for TOD area investments *through 2100*. 

Source: PBR Draft
Hypothetical infrastructure concept – for demonstration purposes only
Hypothetical infrastructure concept – for demonstration purposes only
Hypothetical infrastructure concept – for demonstration purposes only
Hypothetical infrastructure concept – for demonstration purposes only
Flexible Adaptation Pathways – Objective and Options

Option 1
(Protect and Pump)

Option 2
(Raise and Restore)

No Action

Option 3
(Barriers and Bulkheads)

Option 4
(Retreat and Restore)

**Objective:** Ensure adequate infrastructure capacity and *flood protection* for TOD area investments through 2100
Flexible Adaptation Pathways - Triggers, Timing, and Thresholds

Option 1  
(Protect and Pump)

Option 2  
(Raise and Restore)

No Action

Option 3  
(Barriers and Bulkheads)

Option 4  
(Retreat and Restore)

Objective: Ensure adequate infrastructure capacity and *flood protection* for TOD area investments through 2100

Sea level rise (feet)

Gradual climate change

Rapid climate change

<table>
<thead>
<tr>
<th>Year</th>
<th>2020</th>
<th>2040</th>
<th>2060</th>
<th>2080</th>
<th>2100</th>
<th>2120</th>
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<td>No Action</td>
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<td>Option 3</td>
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<td>Option 4</td>
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</table>

ARUP
Flexible Adaptation Pathway - Map

Option 1
(Protect and Pump)

Option 2
(Raise and Restore)

No Action

Option 3
(Barriers and Bulkheads)

Option 4
(Retreat and Restore)

Sea level rise (feet)

Gradual climate change

Rapid climate change

Adaptation Trigger
Transfer station
Tipping Point
Flexible Adaptation Pathways

Option 1 (Protect and Pump)
Option 2 (Raise and Restore)
No Action
Option 3 (Barriers and Bulkheads)
Option 4 (Retreat and Restore)

Sea level rise (feet)
Gradual climate change
Rapid climate change

Pathways
1
2
3
4
5
6
7
8
9

Adaptation Trigger
Transfer station
Tipping Point

ARUP
## Flexible Adaptation Pathways – Evaluate (Near-Term)

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<th>Costs</th>
<th>Benefits</th>
<th>Net Present Value</th>
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<td>Pathways</td>
<td>Costs</td>
<td>Benefits</td>
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<td>9</td>
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<td>+ +</td>
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</table>
Flexible Adaptation Pathway – Hypothetical

Option 1  
(Protect and Pump)

Option 2  
(Raise and Restore)

No Action

Option 3  
(Barriers and Bulkheads)

Option 4  
(Retreat and Restore)

Sea level rise (feet)

Gradual climate change

Rapid climate change

Adaptation Trigger  
Transfer station  
Tipping Point
Flexible Adaptation Pathway

Core Findings (Hypothetical)

- Port and waterfront parcels require protection in all scenarios (no-regrets solution)

- Raising parcels is ineffective as a standalone solution (eventual transfer essential)

- Implementing seawalls or tide barriers too early could be economically inefficient

- Restoration combined with protection leads to co-benefits and high NPV

- Upfront costs of hard infrastructure can be deferred but only temporarily

- Early commitment to protection or retreat focused options promote path-dependence
Flexible Adaptation Pathway

<table>
<thead>
<tr>
<th>Trigger</th>
<th>Action (Hypothetical)</th>
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<tbody>
<tr>
<td>SLR 1ft</td>
<td>• Initiate comprehensive flexible adaptation pathways study</td>
</tr>
<tr>
<td>2020-2030</td>
<td></td>
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</table>
| SLR 2ft  | • Raise all waterfront parcels  
| 2030-2040| • Restore lower Iwilei wetland |
| SLR 3ft  | • Install pump stations |
| 2040-2060|                       |
| SLR 4ft  | • Construct tidal barriers  
| 2060-2080| • Reinforce waterfront bulkheads |
| SLR 5ft  | • Monitoring |
| 2070-2100|                       |
| SLR 6ft  | • Evaluate future plans |
| 2080-2120|                       |
Flexible Adaptation Pathways - Benefits

• Providing flexibility to adapt infrastructure planning to uncertain climate change outcomes
• Avoiding lock-in decisions and identifies near-term ‘no regret’ options
• Clearly outlining future decision (trigger) points for investment
• Presenting approachable framework for cost-benefit analysis
• Mapping out achievable pathways towards successful future outcomes
‘Real’ Recommendations for Implementation (2020-2030)

- Conduct demonstration study focusing on large scale flood infrastructure needs
- Develop initial suite of ‘real options’ - fitted with flexibility to adapt to future change
- Flood risk study required for cost-benefit analysis of ‘real options’
- Map out realistic timing, thresholds, tipping points for decisions
- Pre-work for various adaptation pathways include may include technical studies for groundwater, coastal flooding, and sea level rise
1. District Systems Infrastructure
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The Default Condition is…

Safe since others did it (think protection in groups)

Easy since we’ve done it before (think existing tools)

Known since we can see it (think existing data)

Inexpensive since anything better or new should always cost more (think marketing)

Hard to change (think existing city streets)

Politically nonconfrontational (think NIMBY’ism)

Appropriate since it reflects our culture (think the sexy automobile)

Financeable since the financial system knows how to pay for it (think loan underwriting)
## Facilitating

<table>
<thead>
<tr>
<th></th>
<th>Option 1</th>
<th>Option 2</th>
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<tr>
<td>Life Cycle Cost</td>
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<tr>
<td>LEED® Impact</td>
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<td>Flr to Flr Height</td>
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<td>+</td>
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<td>+</td>
</tr>
<tr>
<td>Roof Impact</td>
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<tr>
<td>Design Change</td>
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</tr>
<tr>
<td>Other System Impact</td>
<td>[✗]</td>
<td>[✓]</td>
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</tbody>
</table>
Signaling
Here is Edward Bear, coming downstairs now,

*bump, bump, bump,*

on the back of his head, behind Christopher Robin. It is, as far as he knows, the only way of coming downstairs, but sometimes he feels that there really is another way, if only he could stop bumping for a moment and think of it.

E.H. Sheppard