



University of
Zurich^{UZH}

Energy Patterns for Web: An Exploratory Study

Pooja Rani, Jonas Zellweger, Veronika Kousadianos,
Luis Cruz, Timo Kehrer, Alberto Bacchelli

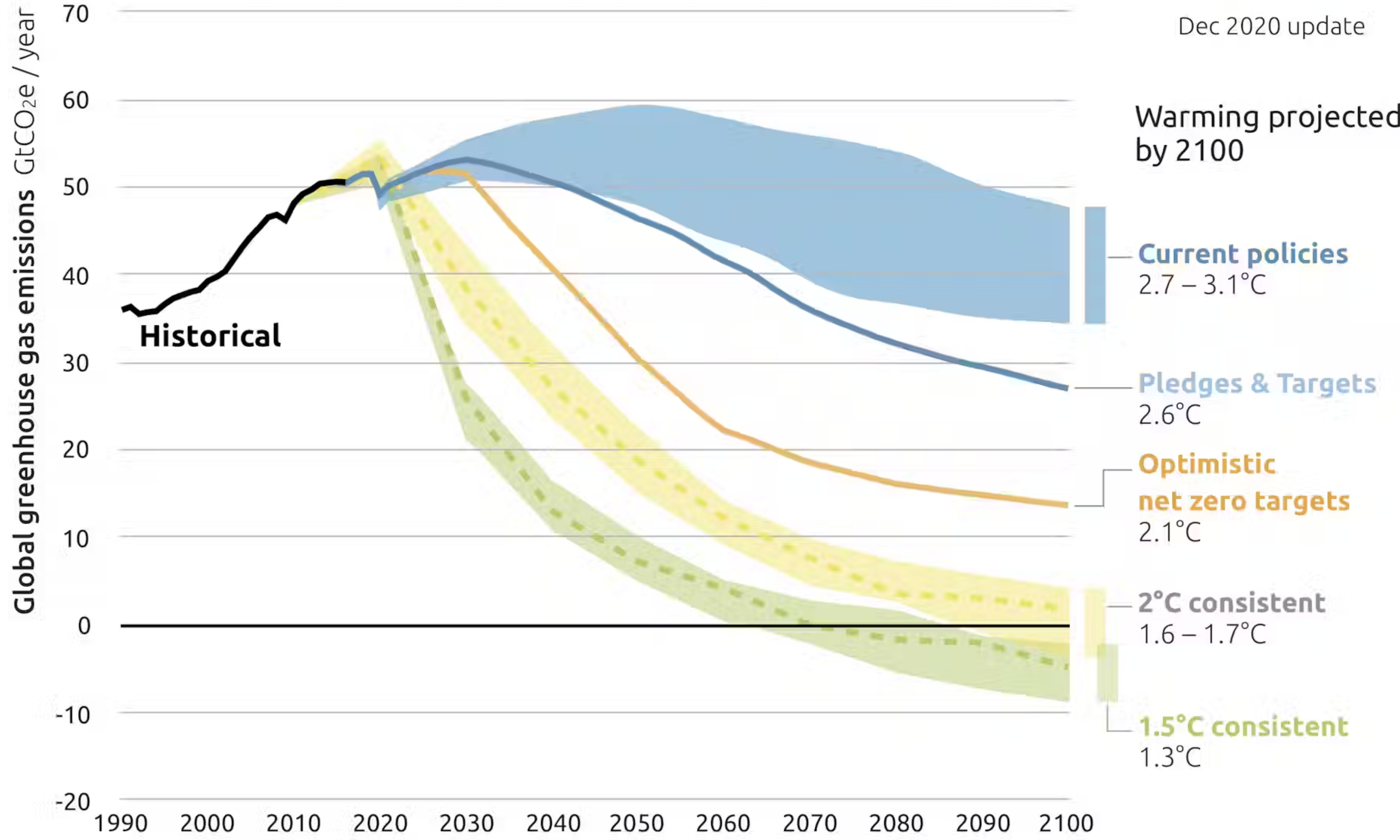
University of Zurich, Switzerland

2100 WARMING PROJECTIONS

Emissions and expected warming based on pledges and current policies



Dec 2020 update



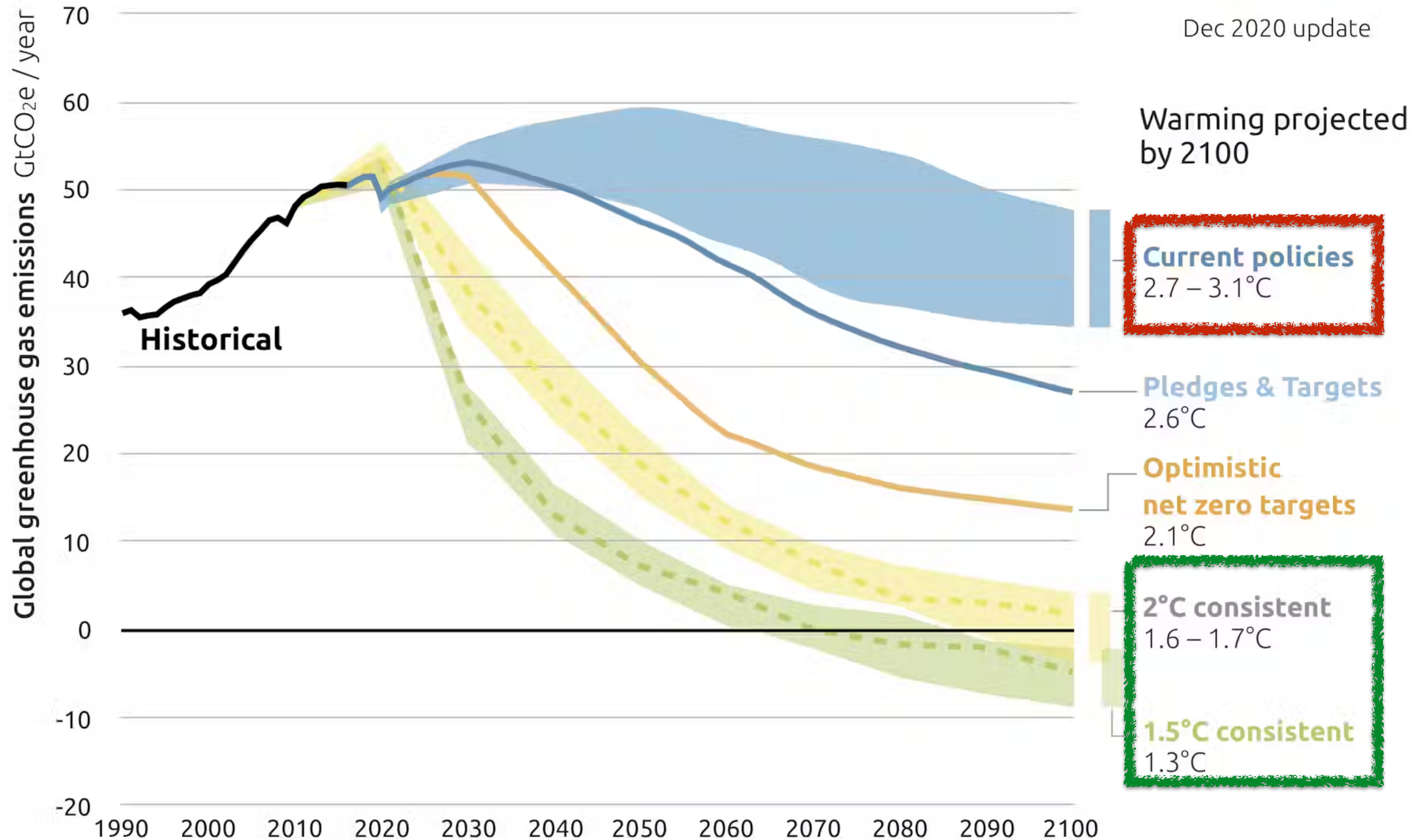
2

2100 WARMING PROJECTIONS

Emissions and expected warming based on pledges and current policies



Dec 2020 update



Is it our problem?

```
/**  
 * TODO  
 */  
  
public void log(String s) {  
    System.out.println(s);  
}
```



Is it our problem?

Around 4.6 billion people use the internet every day.

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05-09-2019 | CO.DESIGN

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Yes, websites have a carbon footprint

The internet consumes a lot of electricity. 416.2TWh per year to be precise. To give you some perspective, that's more than the entire United Kingdom.

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Globally, the average web page produces approximately **0.8 grams** CO2 equivalent per pageview. For a website with 10,000 monthly page views, that's **102 kg** CO2e per year.

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What can we do?

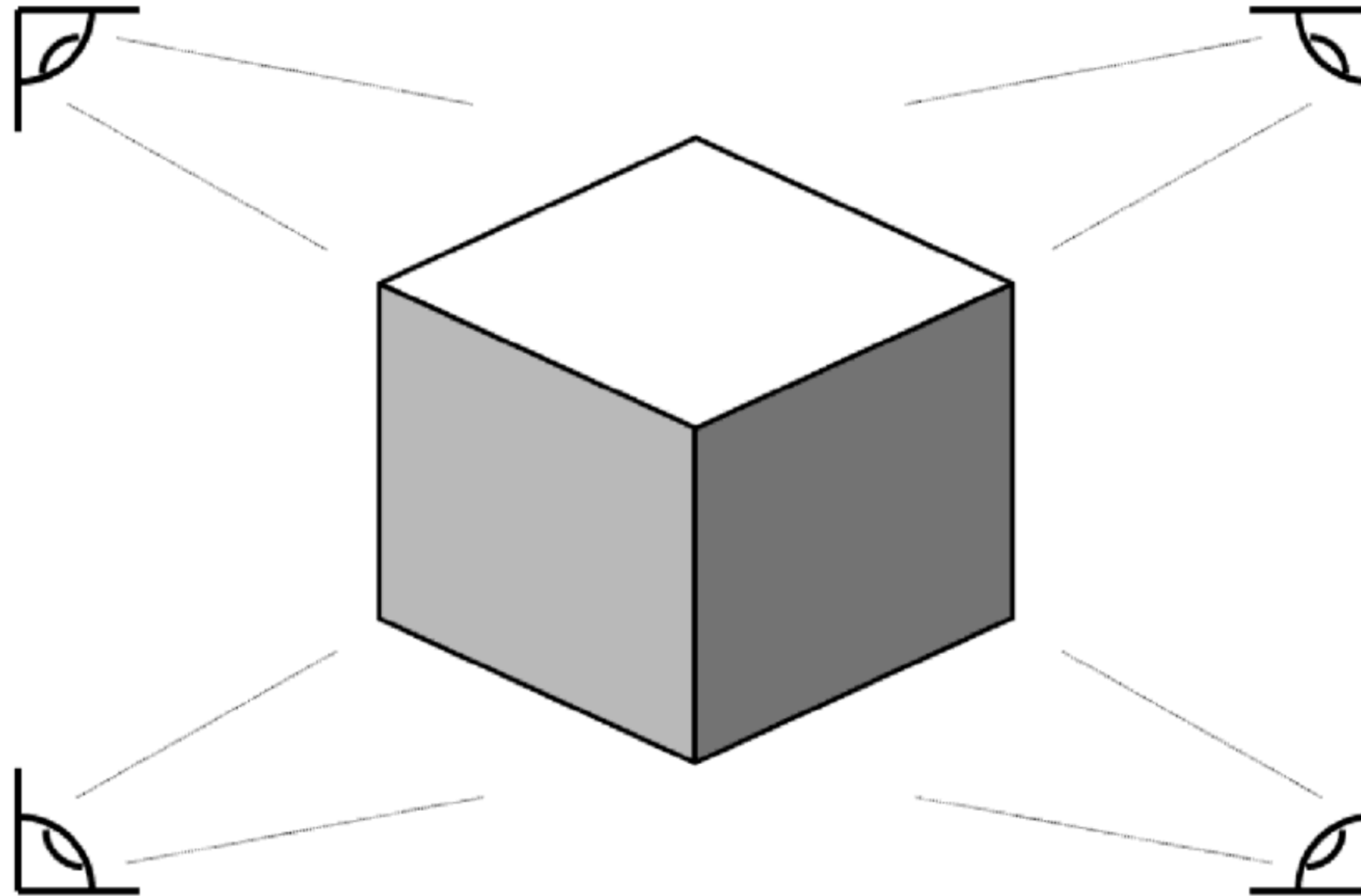
Being aware of energy-related coding practices in web world can help us make better choices

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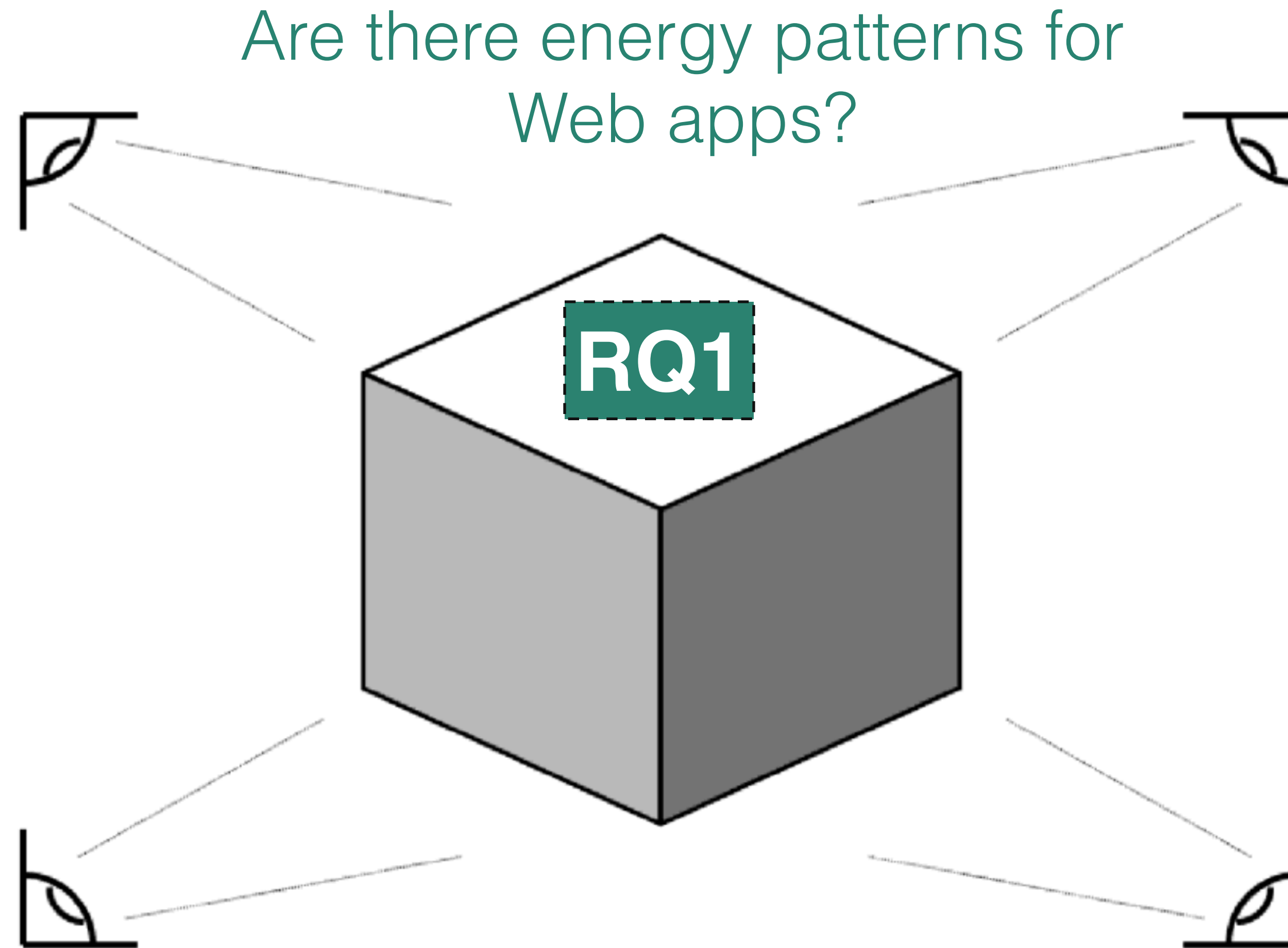
Energy patterns

Being aware of energy-related coding practices in web world can help us make better choices

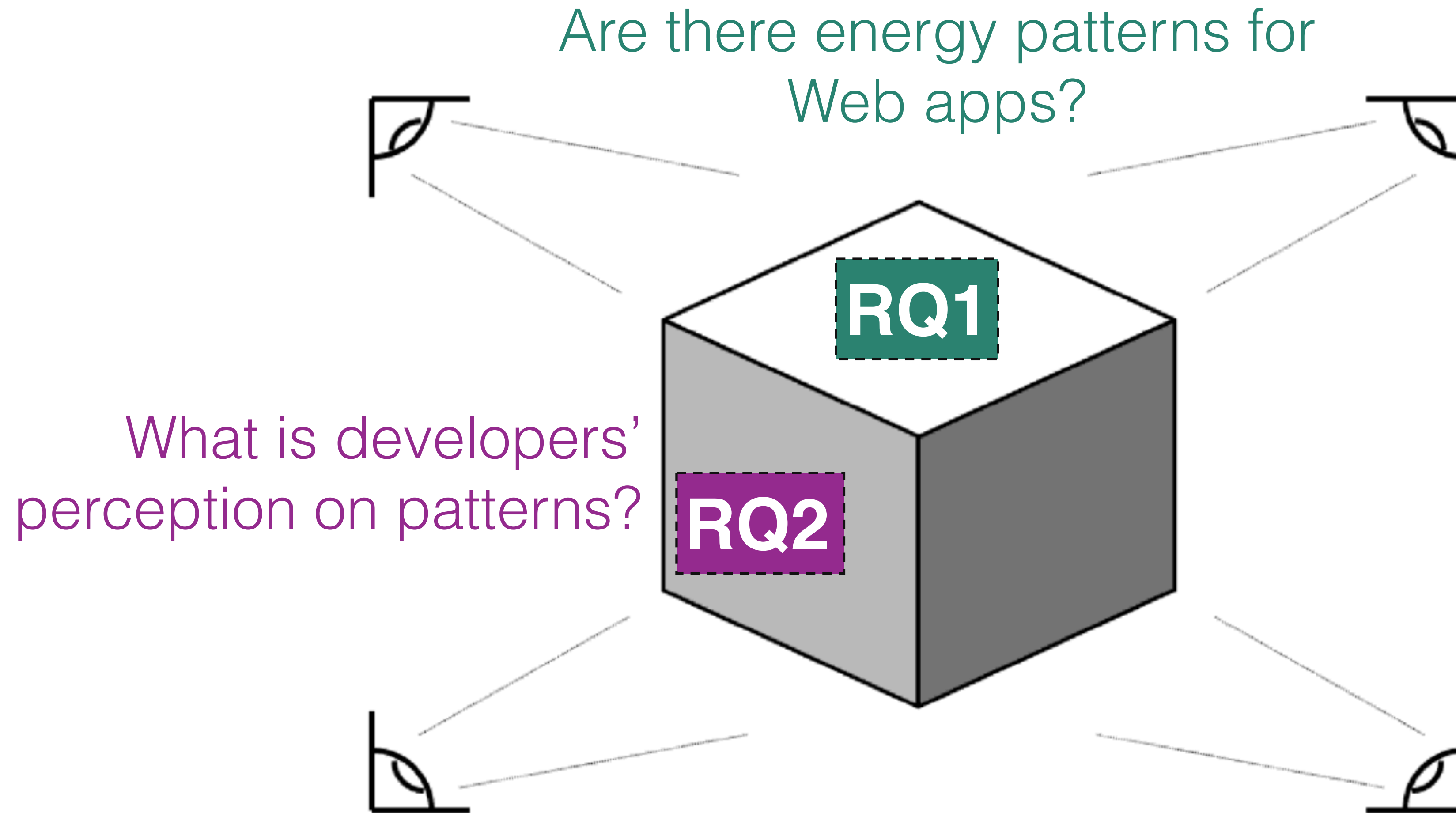
It requires a multi-perspective view



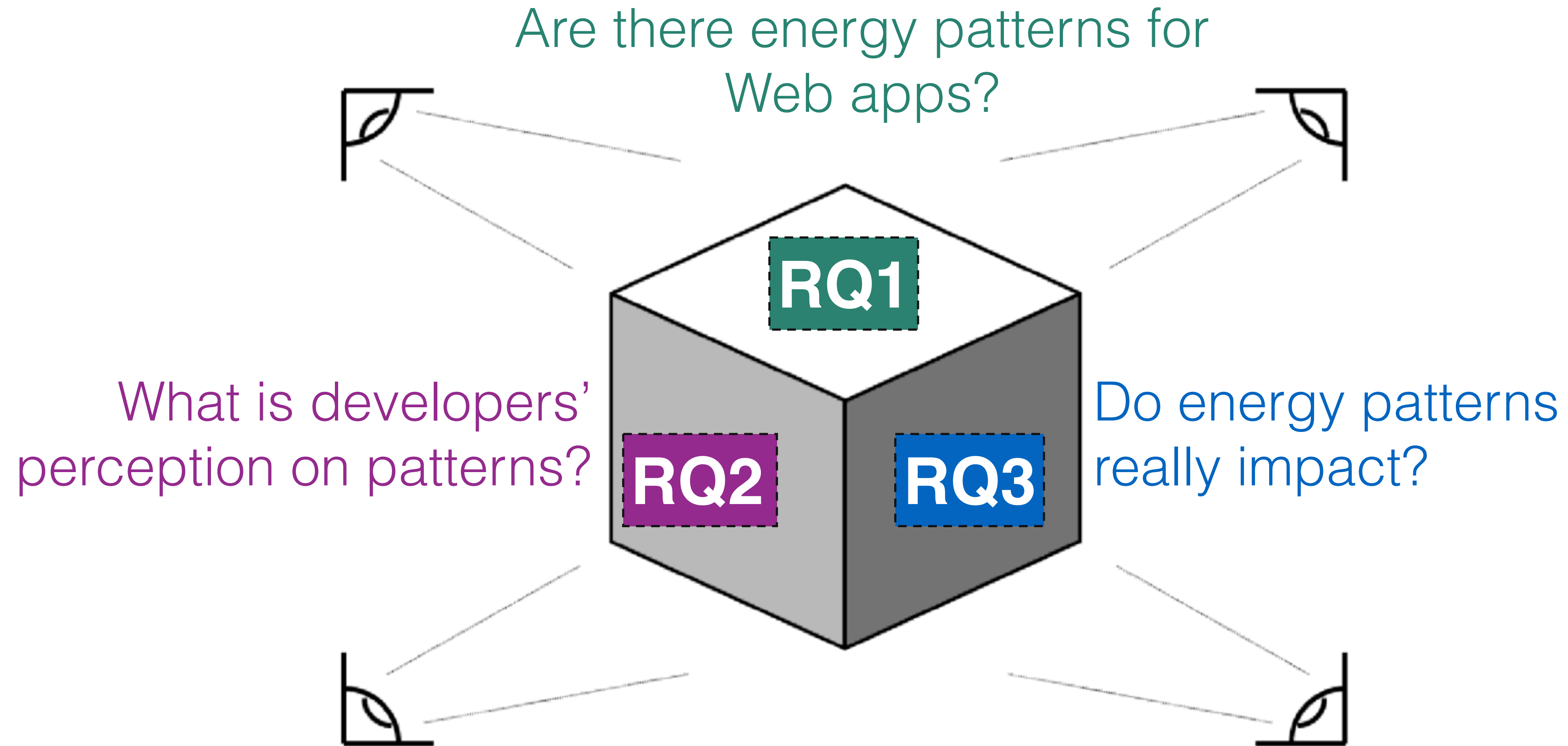
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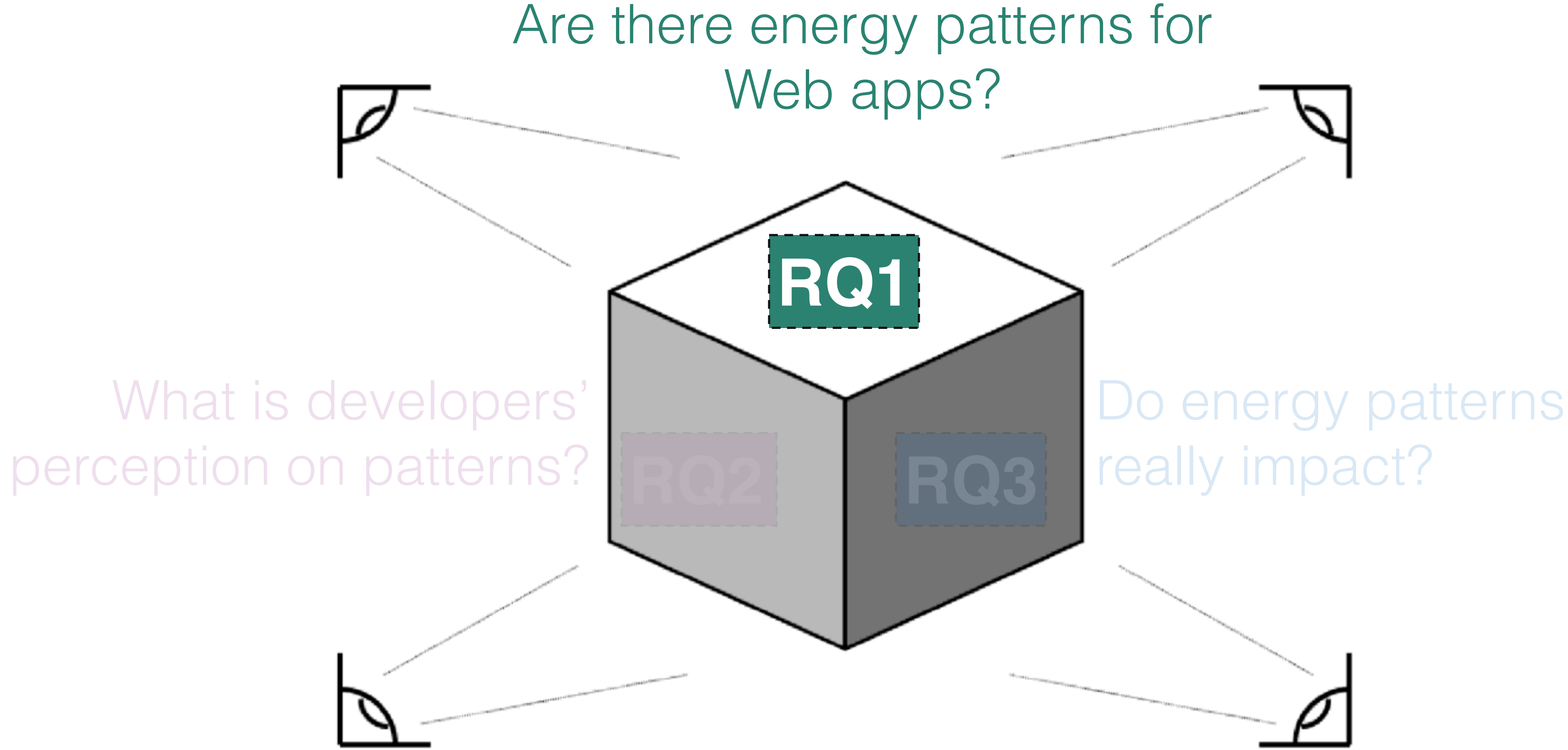
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It requires a multi-perspective view



RQ1: Energy Patterns for the Web

22 Mobile energy patterns

Dark UI Colors

Provide a dark UI colour theme to save battery.

Dynamic Retry Delay

Whenever an attempt to access a resource has failed, increase the interval of time waited before asking it

Open Only When Necessary

Open/start resources/services only when they are strictly necessary.

Push Over Poll

Use push notifications to receive updates from resources instead of actively querying resources (polling)

Power Awareness

Have a different behavior when device is connected/disconnected to a power station

Wifi Over Cellular

Delay or disable heavy data connections until the device is connected to a WiFi network

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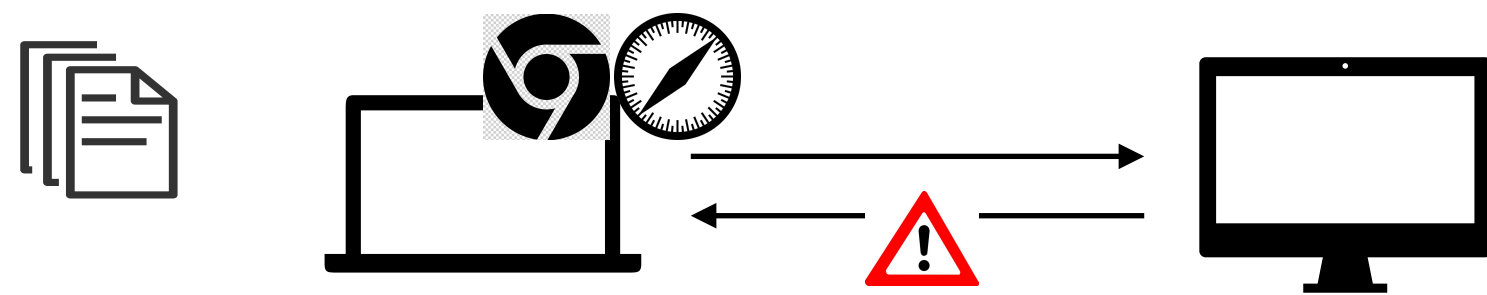
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RQ2: Developers' Perception on Patterns

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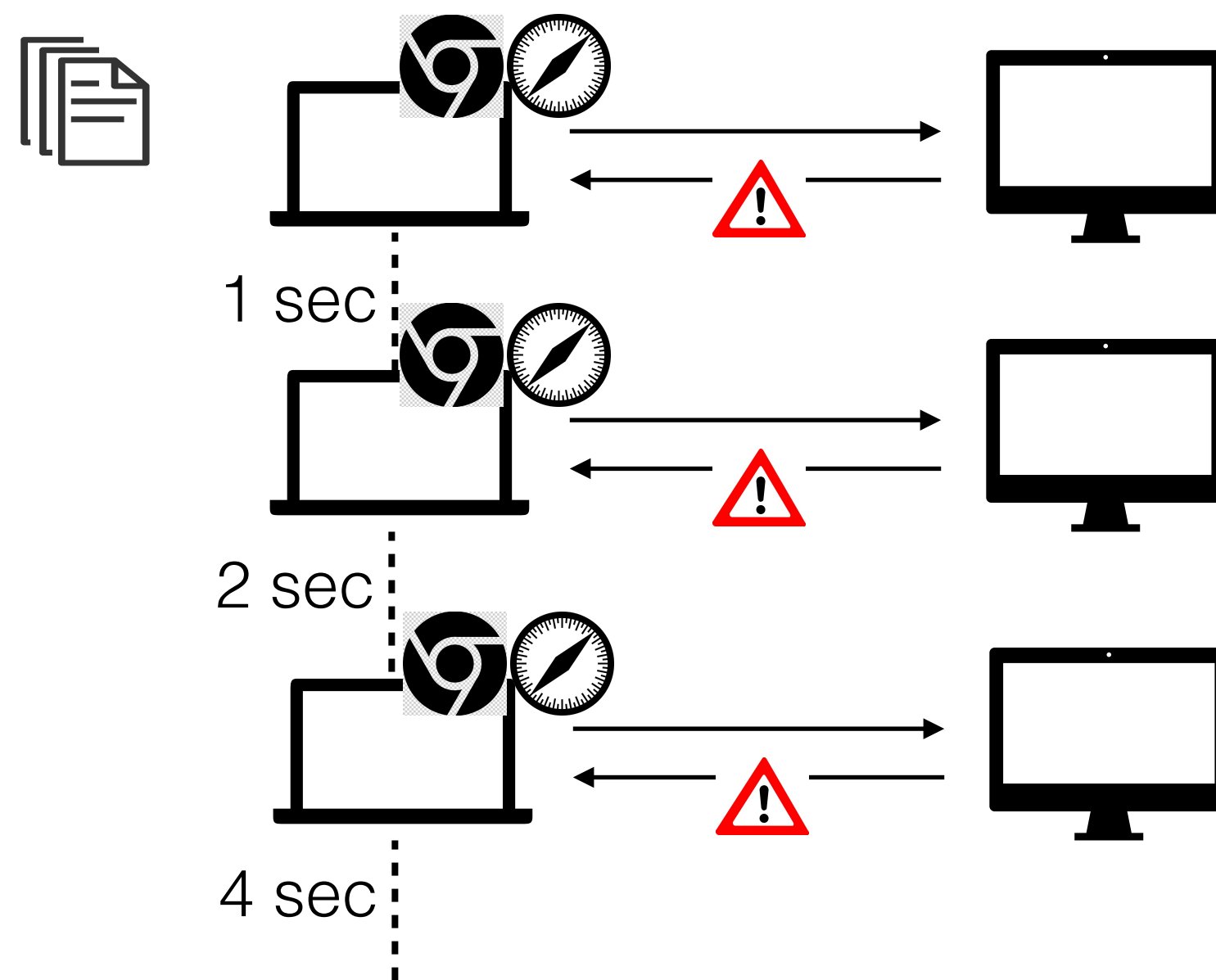
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RQ2: Developers' Perception on Patterns

Dynamic Retry Delay

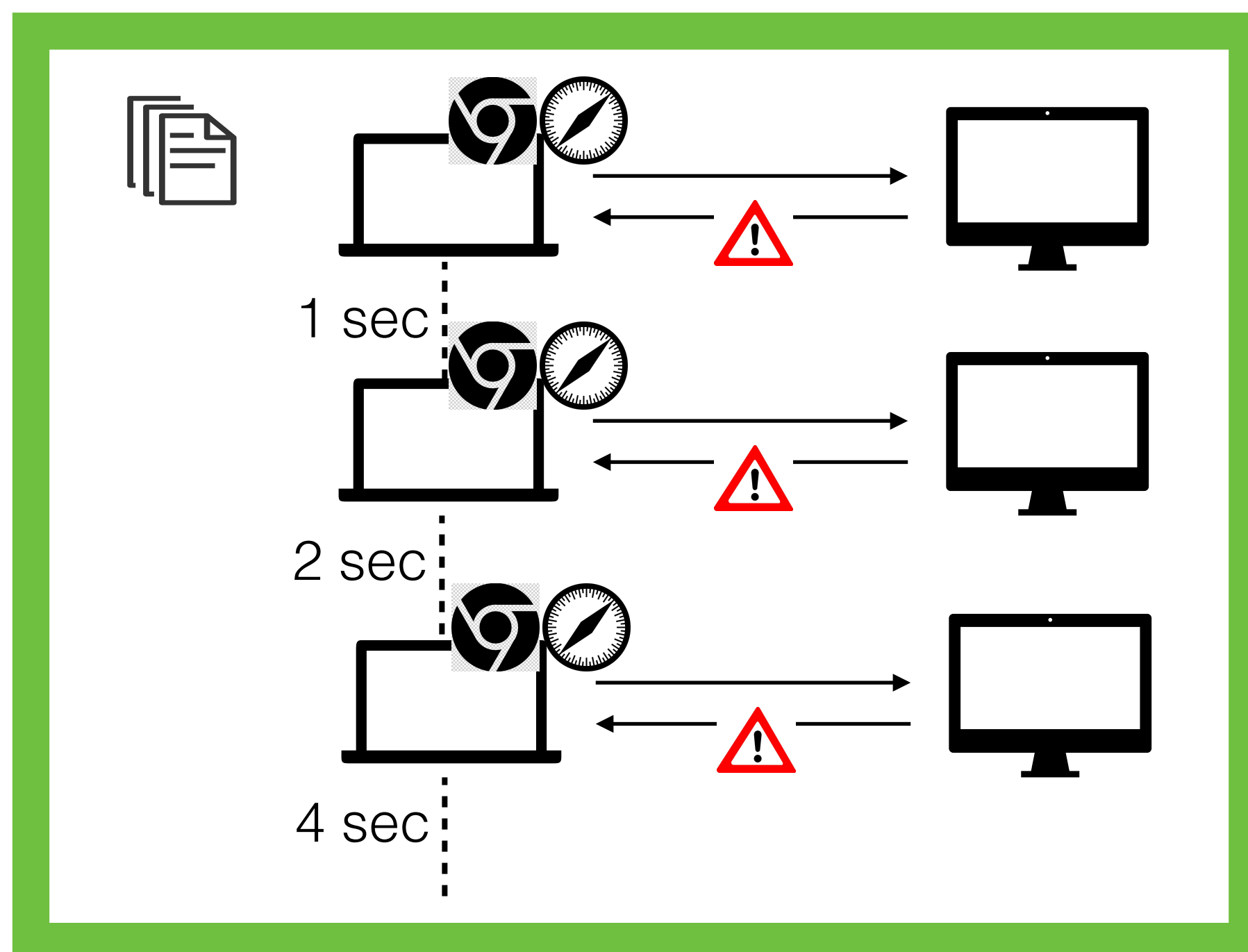
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RQ2: Developers' Perception on Patterns

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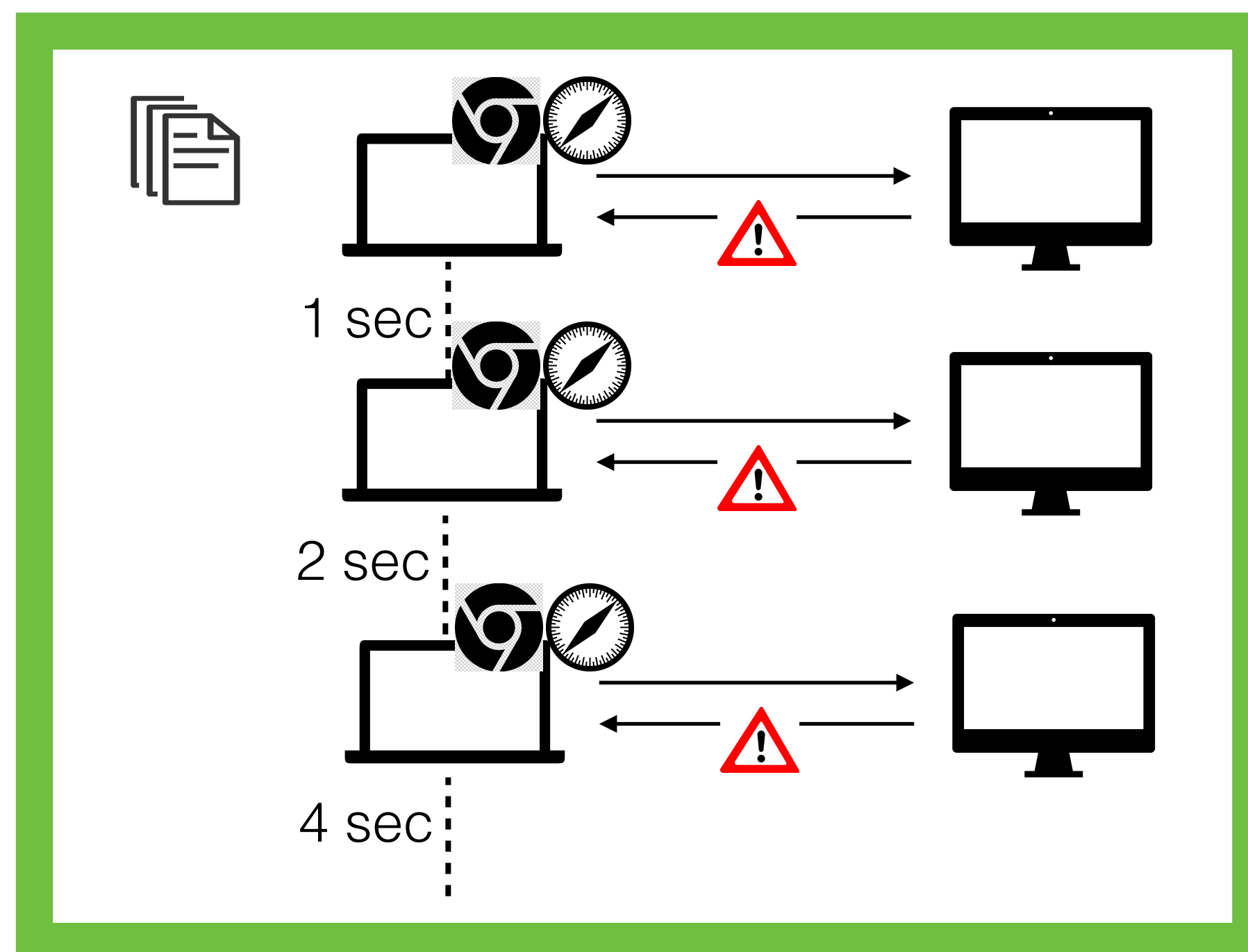


Pattern

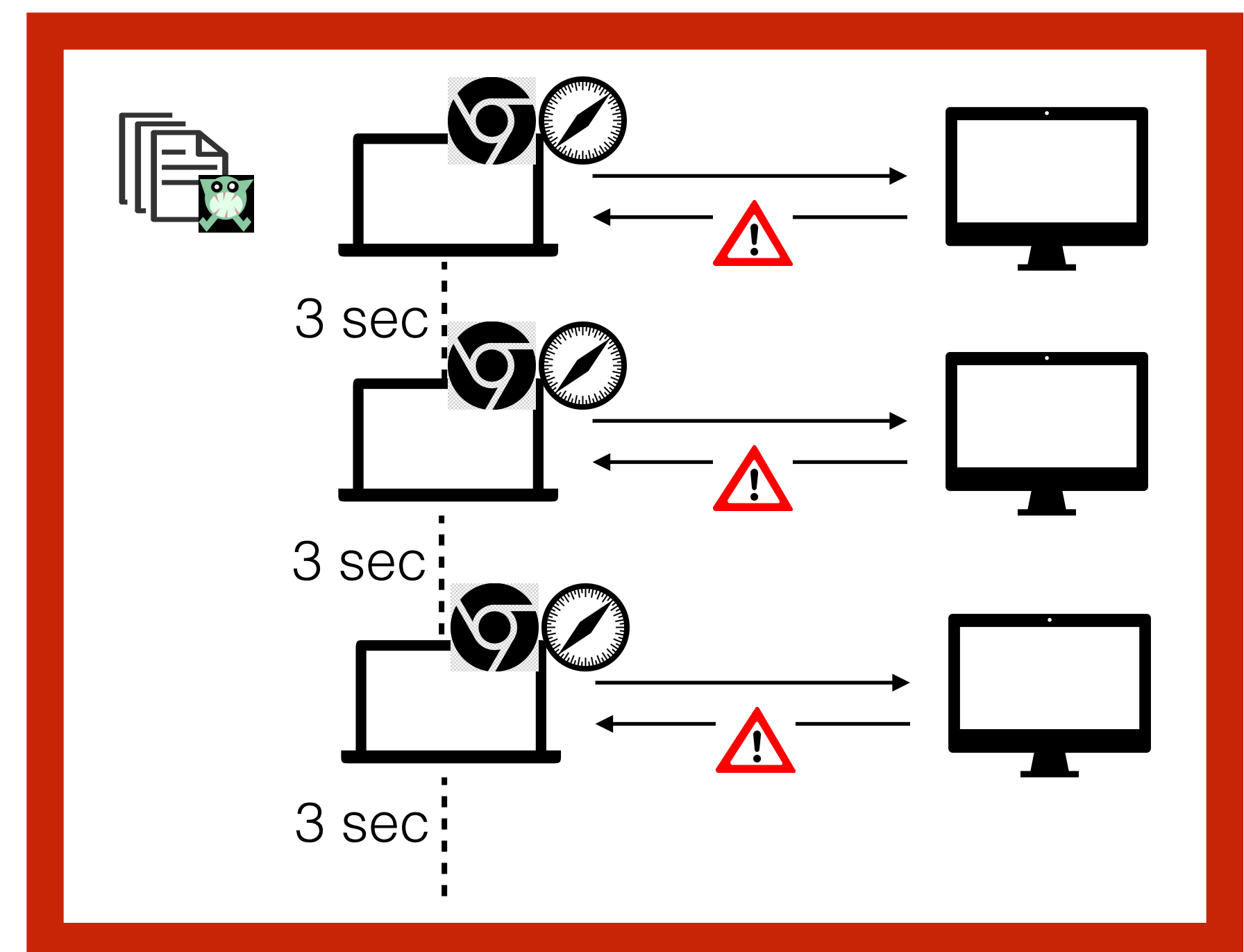
RQ2: Developers' Perception on Patterns

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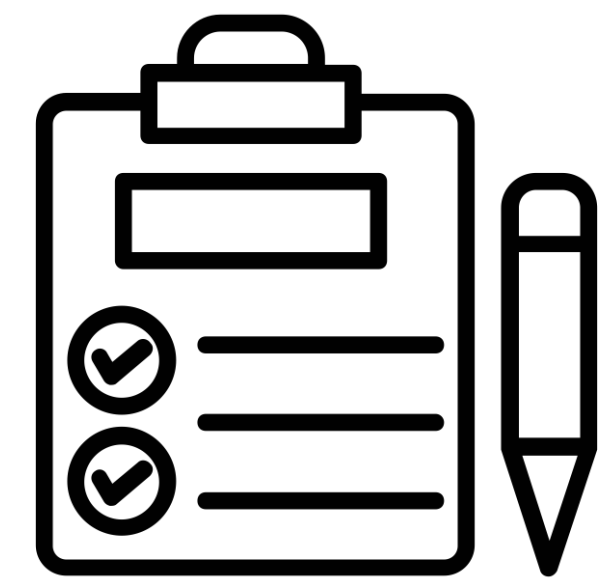
(Anti)pattern

RQ2: Developers' Perception on Patterns

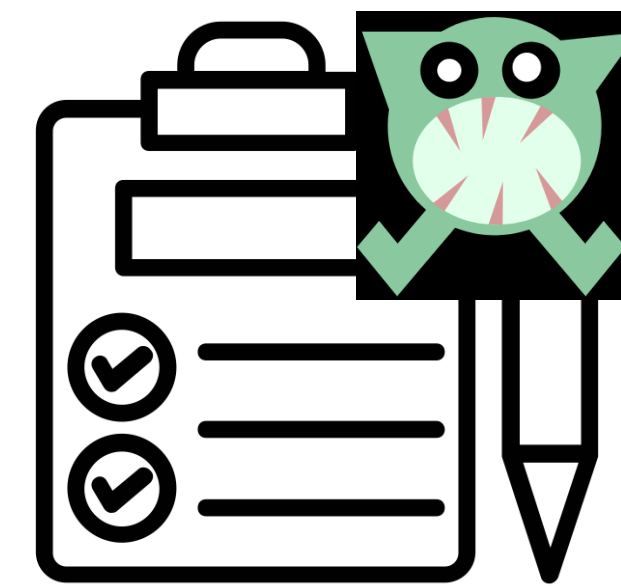


familiarity
on patterns

RQ2: Developers' Perception on Patterns



familiarity
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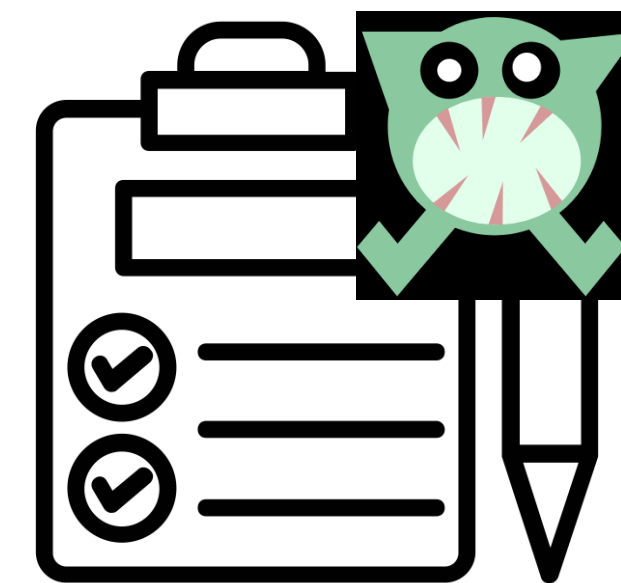


Concerns on
antipatterns

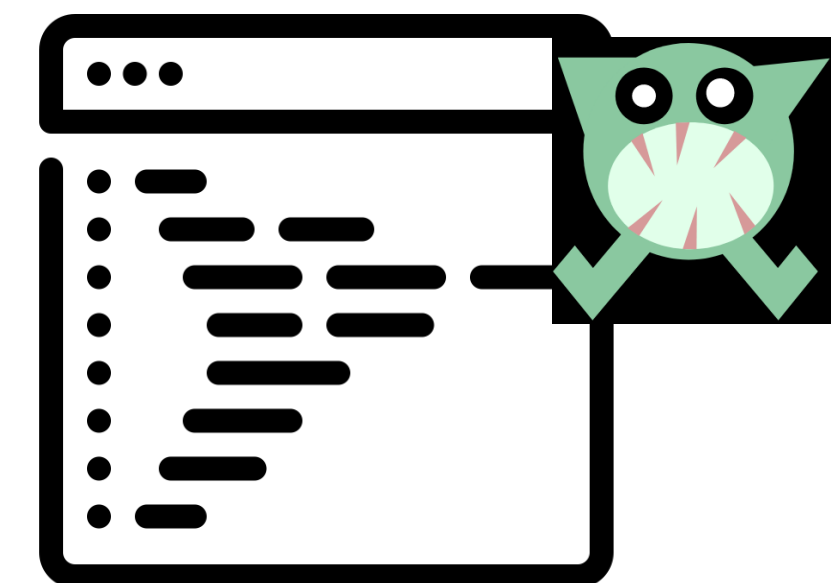
RQ2: Developers' Perception on Patterns



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Concerns on
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Patterns in
source code

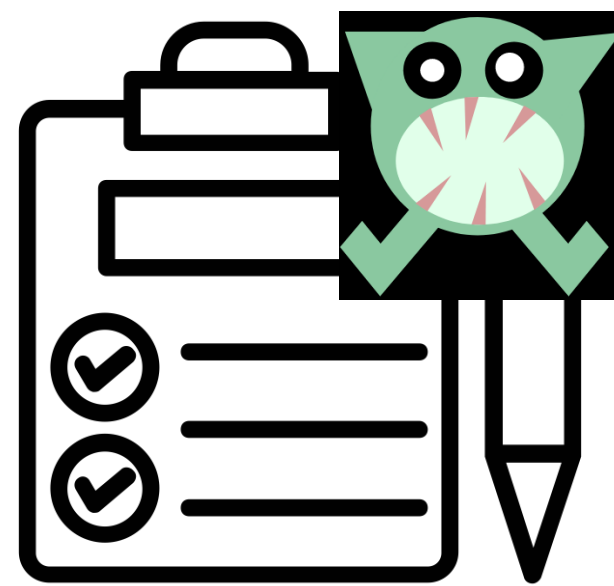
RQ2: Developers' Perception on Patterns



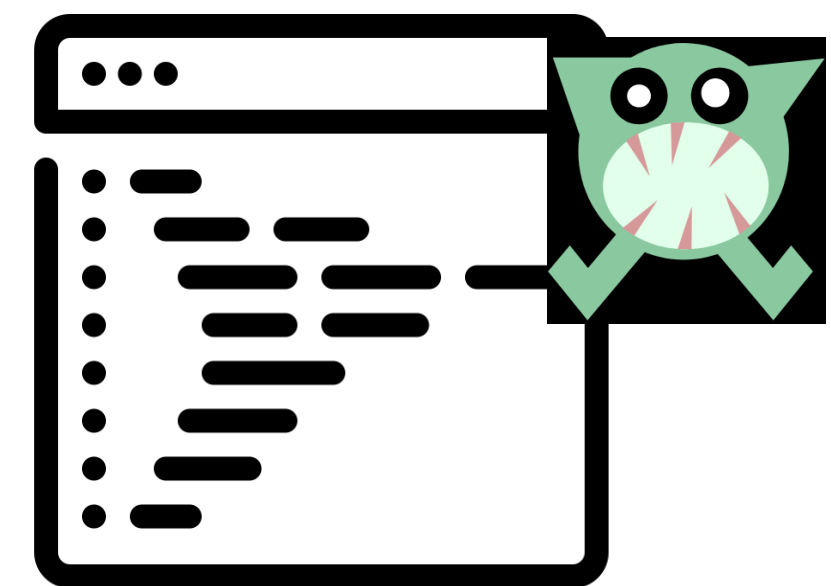
Case study with 6 web developers



familiarity on patterns



Concerns on antipatterns



Patterns in source code



Other questions



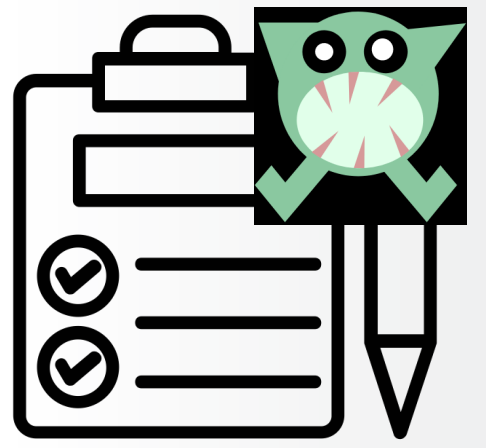
Familiar with Energy Patterns



17%

66%

17%

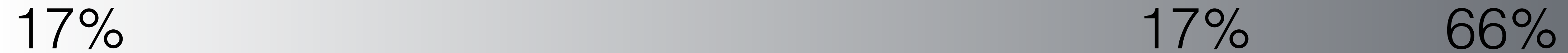


Concerns about Anti-patterns

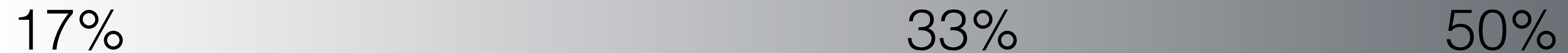
Least concerned

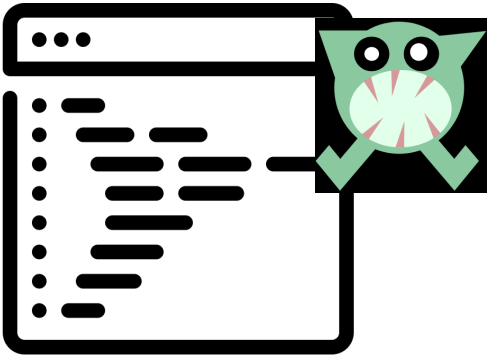
Extremely concerned

Dynamic Retry Delay



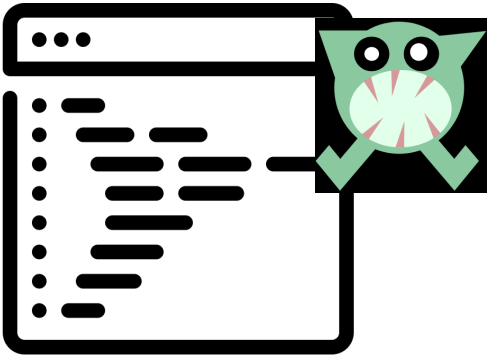
Open Only When Necessary





Energy Patterns in Source code

```
503         message =
504         if not hasattr(self, '_headers_buffer'):
505             self._headers_buffer = []
506             self._headers_buffer.append((" %s %d %s\r\n" %
507                 (self.protocol_version, code, message)).encode(
508                 'latin-1', 'strict'))
509
510     def send_header(self, keyword, value):
511         """Send a MIME header to the headers buffer."""
512         if self.request_version != 'HTTP/0.9':
513             if not hasattr(self, '_headers_buffer'):
514                 self._headers_buffer = []
515             self._headers_buffer.append(
516                 ("%s: %s\r\n" % (keyword, value)).encode('latin-1', 'strict'))
517
518         if keyword.lower() == 'connection':
519             if value.lower() == 'close':
520                 self.close_connection = True
521             elif value.lower() == 'keep-alive':
522                 self.close_connection = False
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```

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✓ 9 patterns found in code

✓ 11 anti patterns in code

✗ 4 not applicable to code

RQ3: Impact of Energy Patterns

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Provide a dark UI colour theme to save battery.

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Wifi Over Cellular

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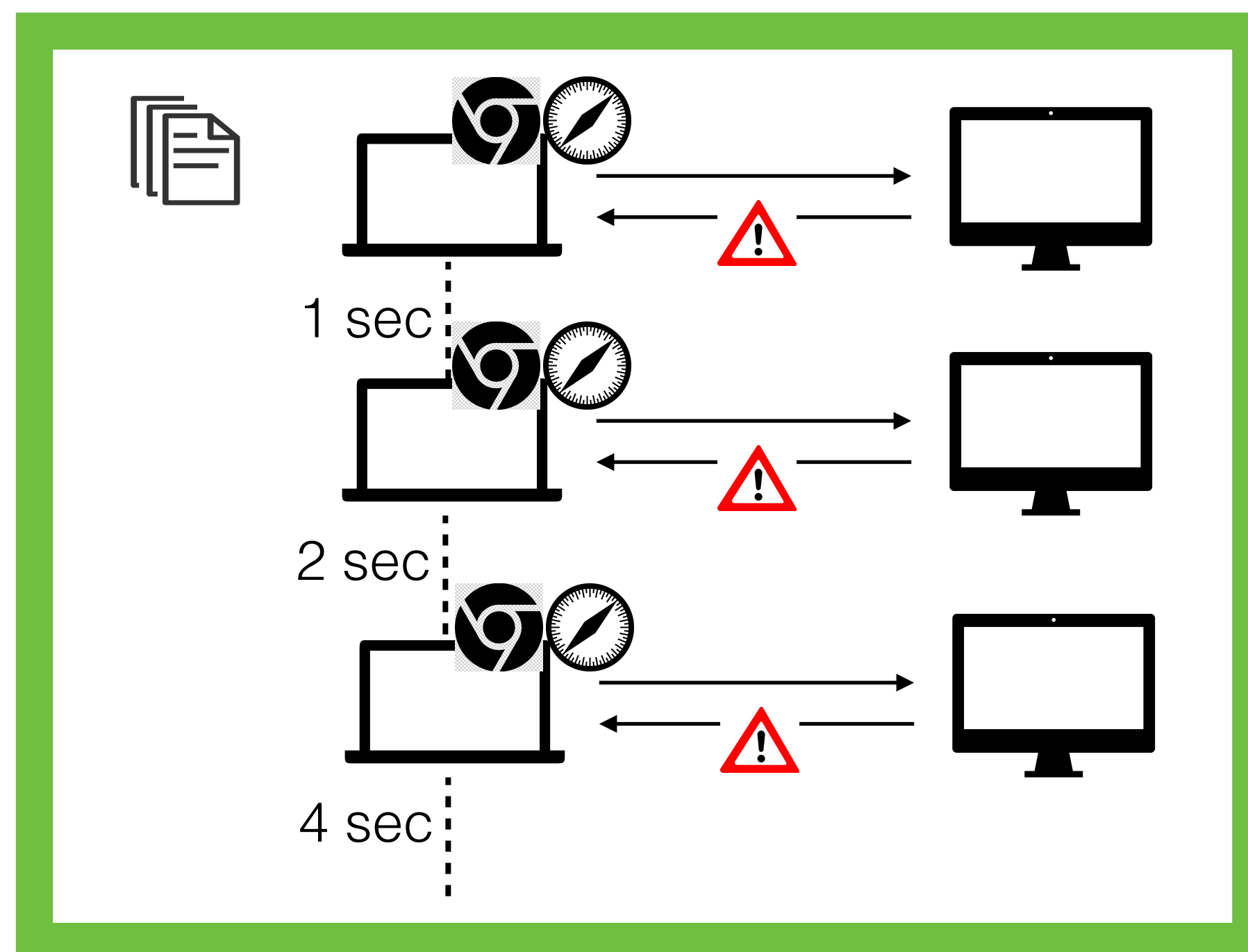


Do they really impact?

RQ3: Impact of Energy Patterns

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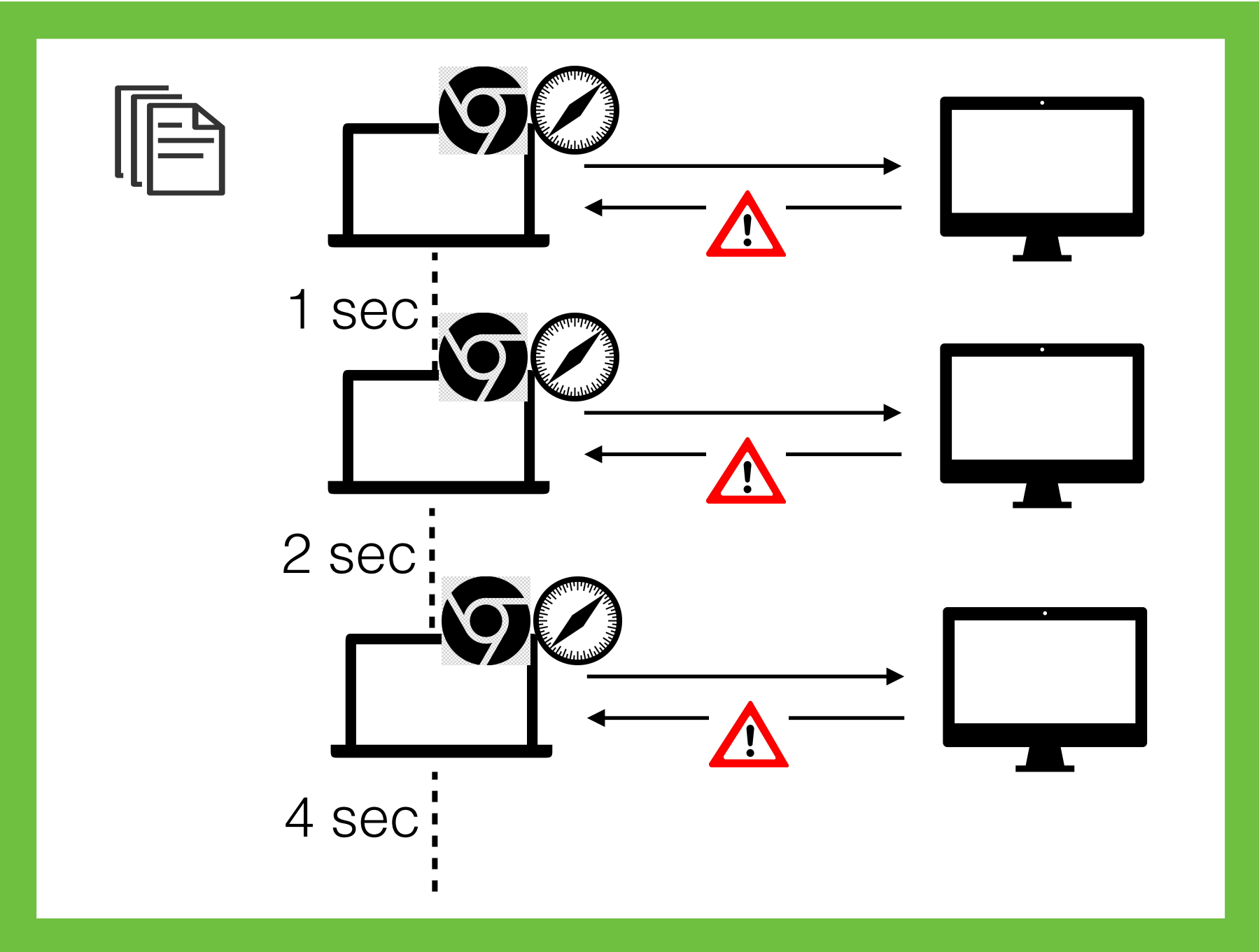


Pattern

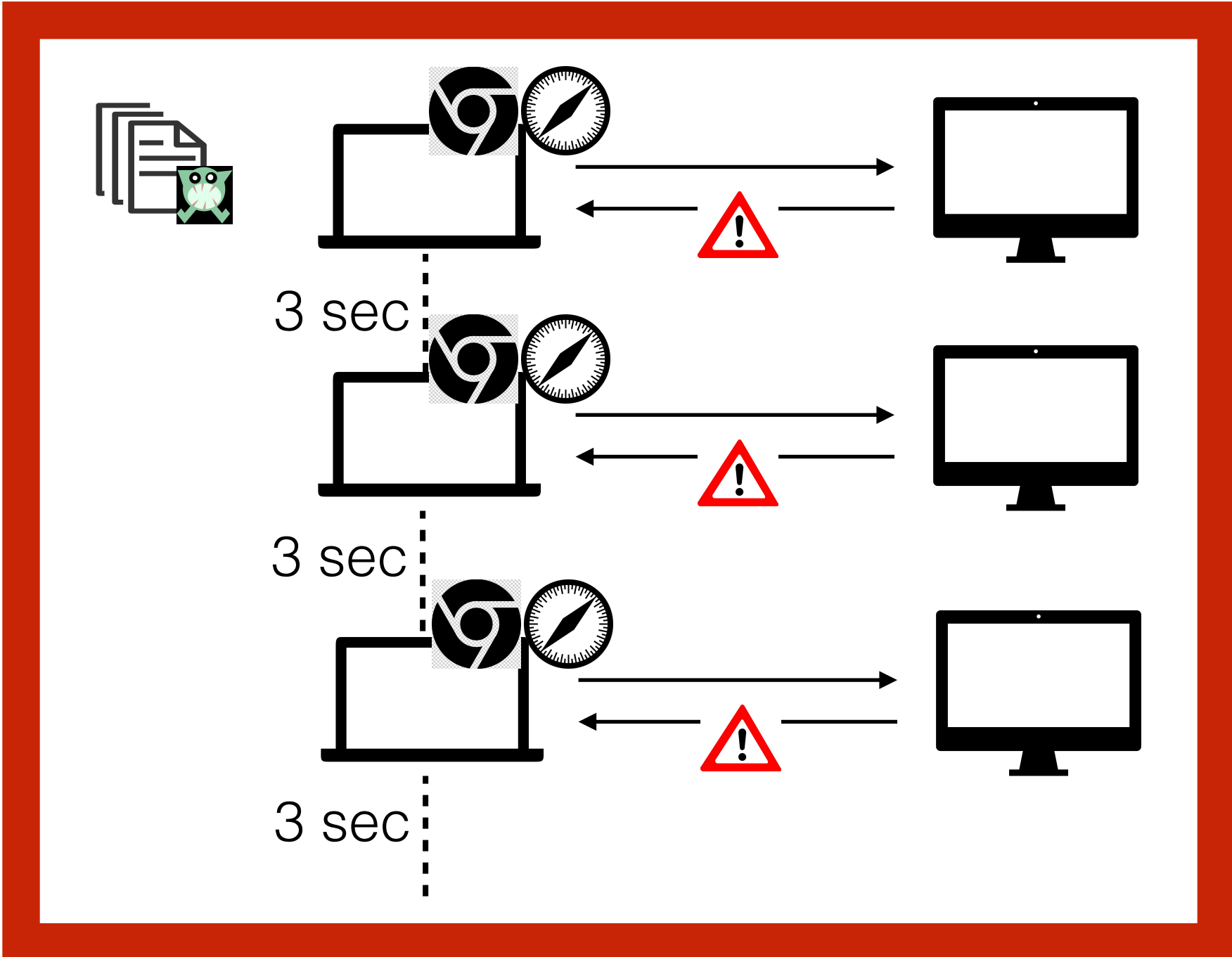
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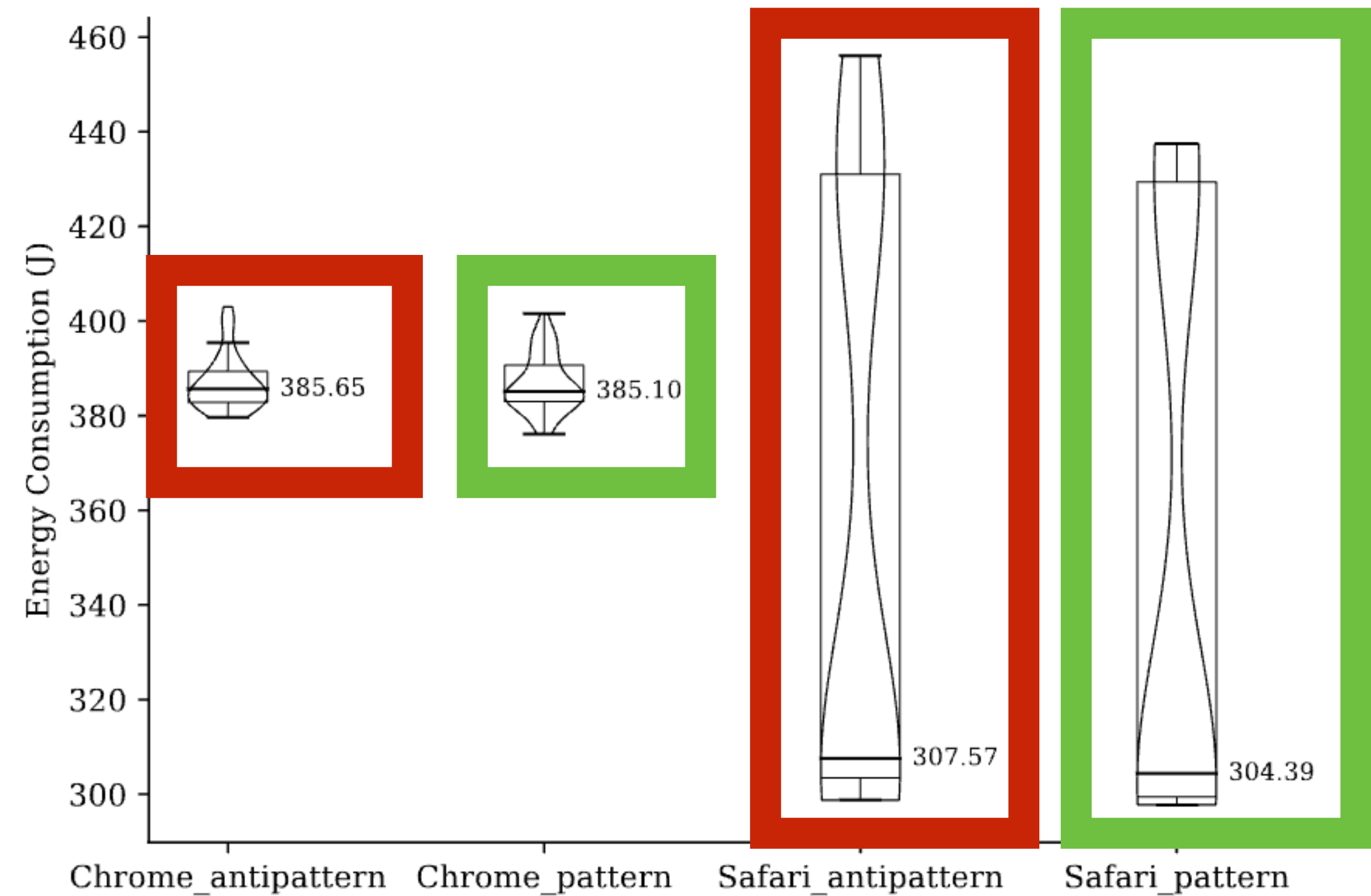


(Anti)pattern

RQ3: Impact of Energy Patterns

Dynamic Retry Delay

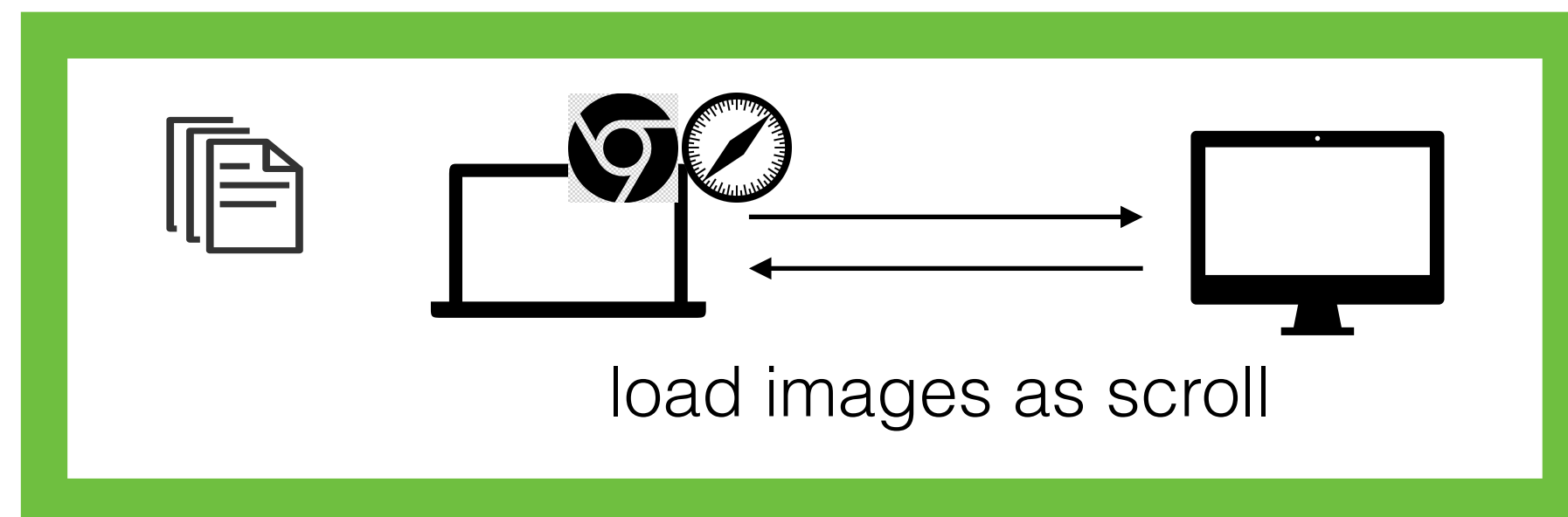
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RQ3: Impact of Energy Patterns

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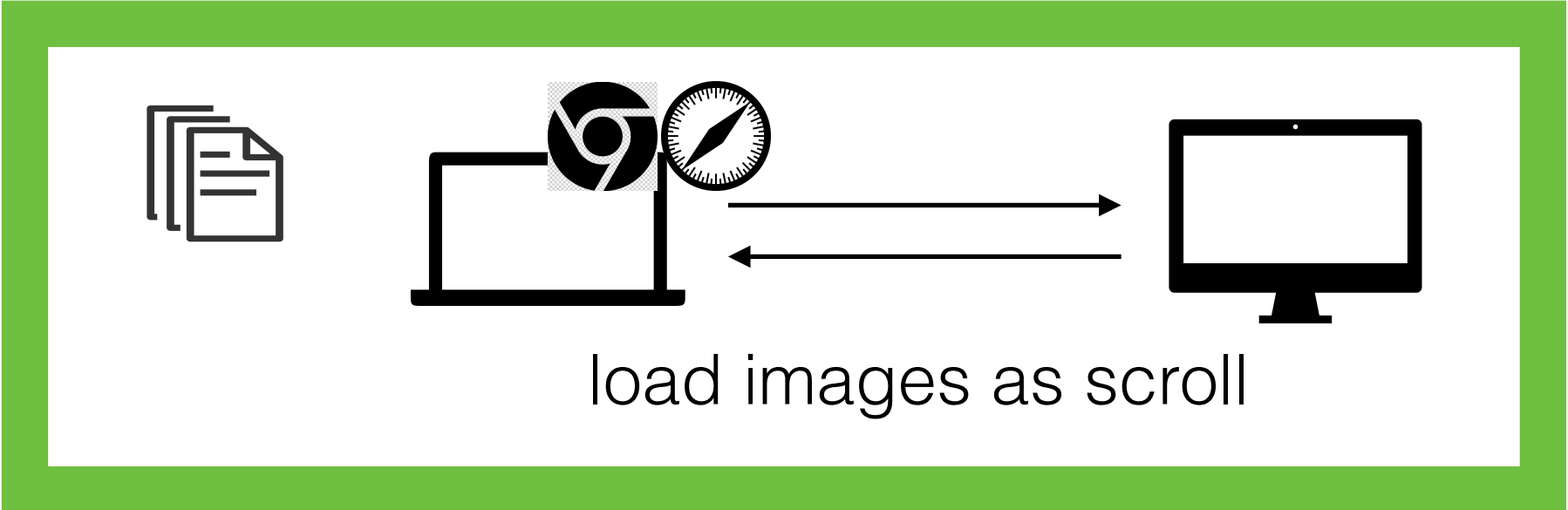


Pattern

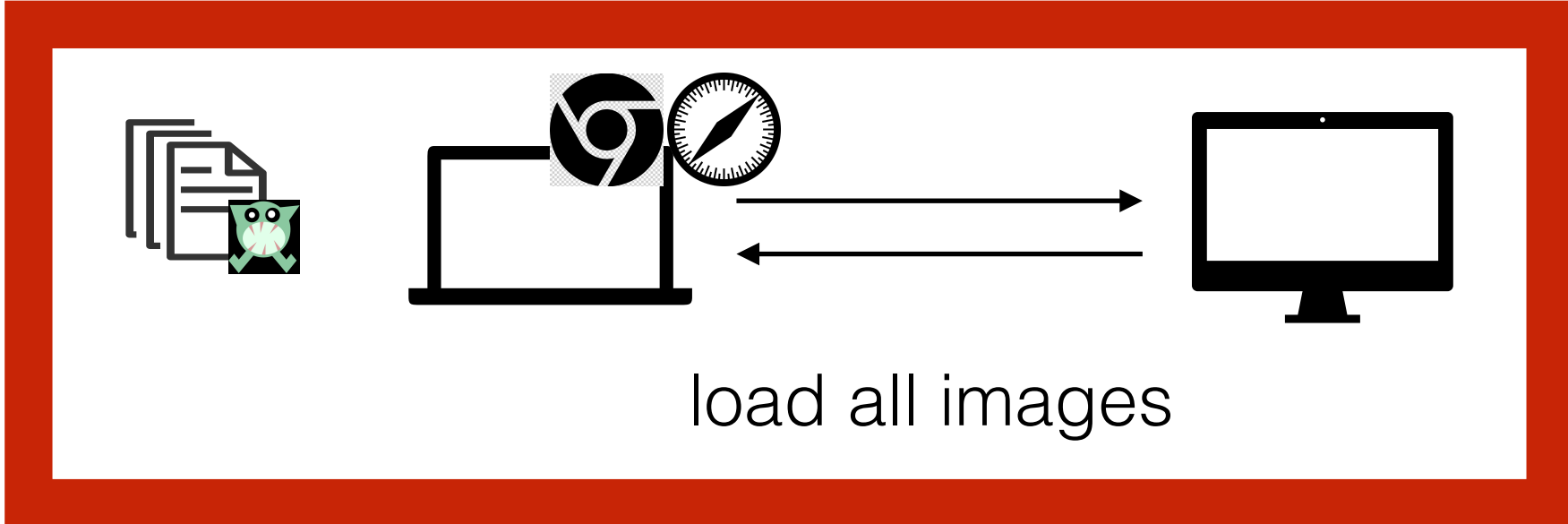
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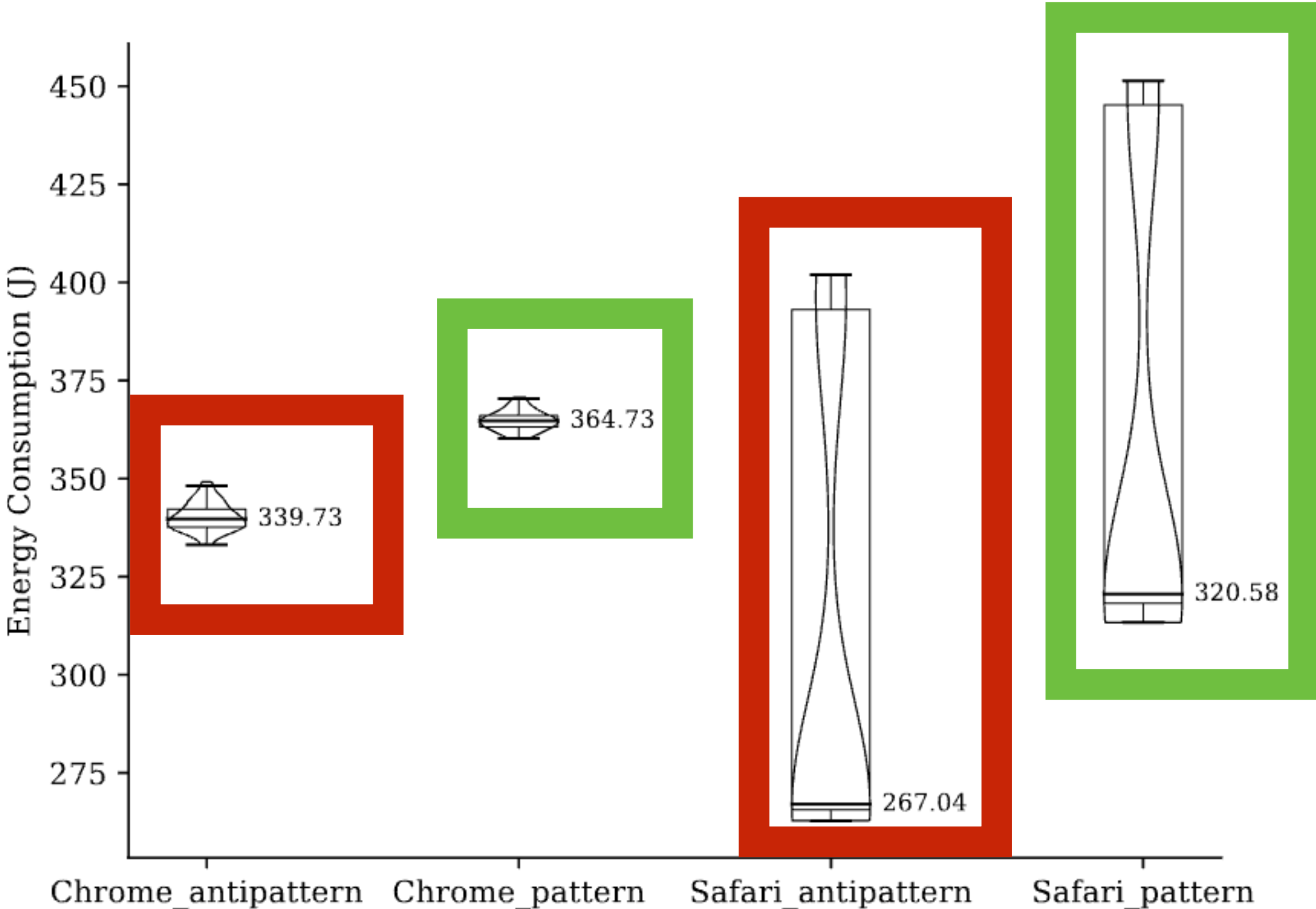


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RQ3: Impact of Energy Patterns

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Takeaways

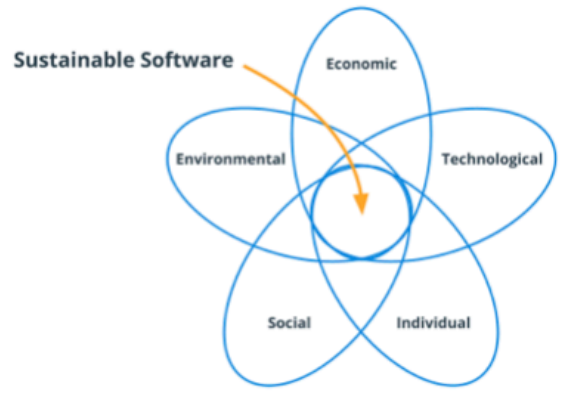
- 83% developers are not familiar with energy patterns.
- Developers are concerned about many anti patterns.
- They could find 16 (anti) patterns in source code.
- Energy impact of energy patterns vary.

Is it my problem?

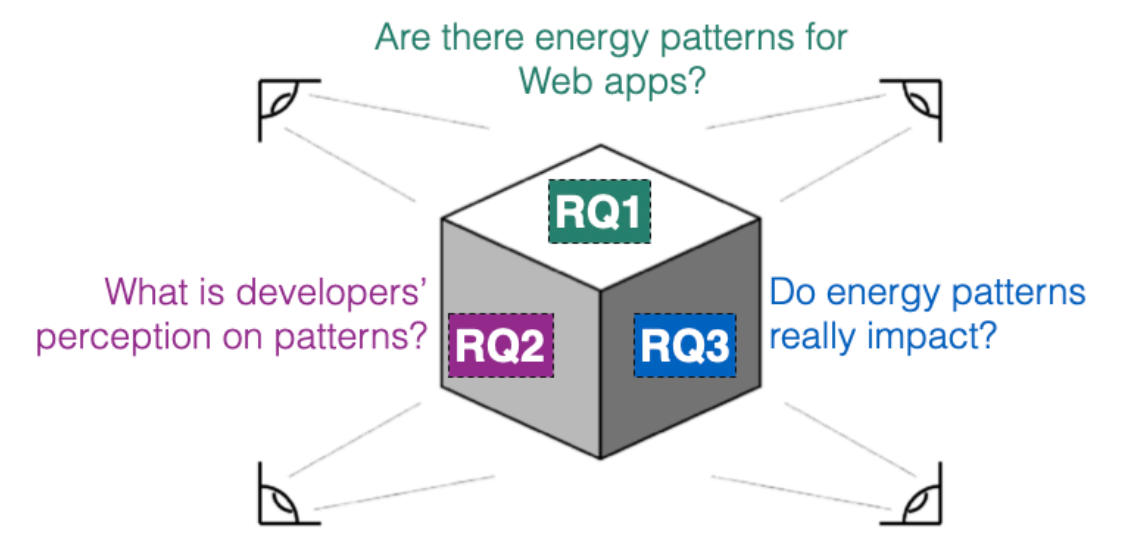
```
/**
 * TODO
 */
public void log(String s) {
    System.out.println(s);
}
```



“Sustainability means meeting our own needs without compromising the ability of future generations to meet their own needs.” (McGill University, 2013)



It requires a multi-perspective view



RQ1: Energy Patterns for the Web

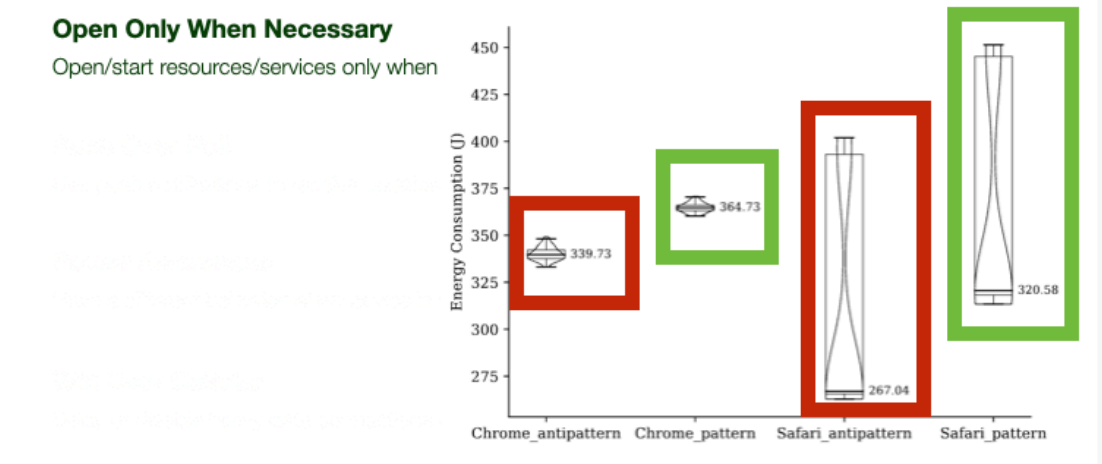
- 20 web energy patterns**
- Dark UI Colors**
Provide a dark UI colour theme to save battery.
- Dynamic Retry Delay**
Whenever an attempt to access a resource has failed, increase the interval of time waited before asking it
- Open Only When Necessary**
Open/start resources/services only when they are strictly necessary.
- Push Over Poll**
Use push notifications to receive updates from resources instead of actively querying resources (polling)
- Power Awareness**
Have a different behavior when device is connected/disconnected to a power station
- Wifi Over Cellular**
Delay or disable heavy data connections until the device is connected to a WIFI network

Energy Patterns in Source code

```
if (isDebugEnabled()) {
    log.debug("Starting...");
} else {
    log.info("Starting...");
}
// ...
if (isDebugEnabled()) {
    log.debug("Ending...");
} else {
    log.info("Ending...");
}
```

- 9 patterns found in code**
- 11 anti patterns in code**
- 4 not applicable to code**

RQ3: Do Energy Patterns impact?



My profile



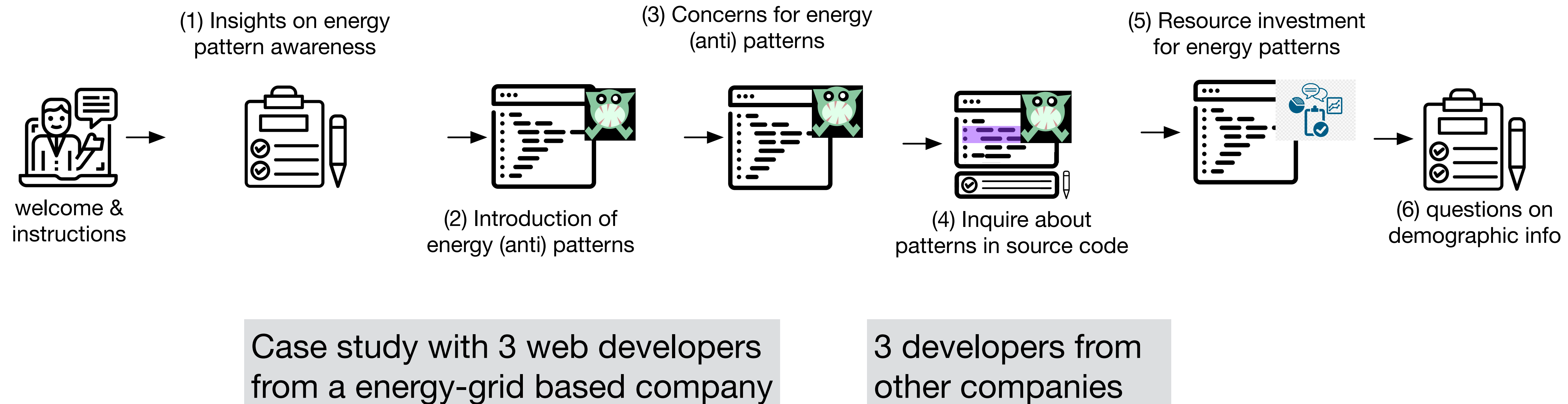
Replication Package



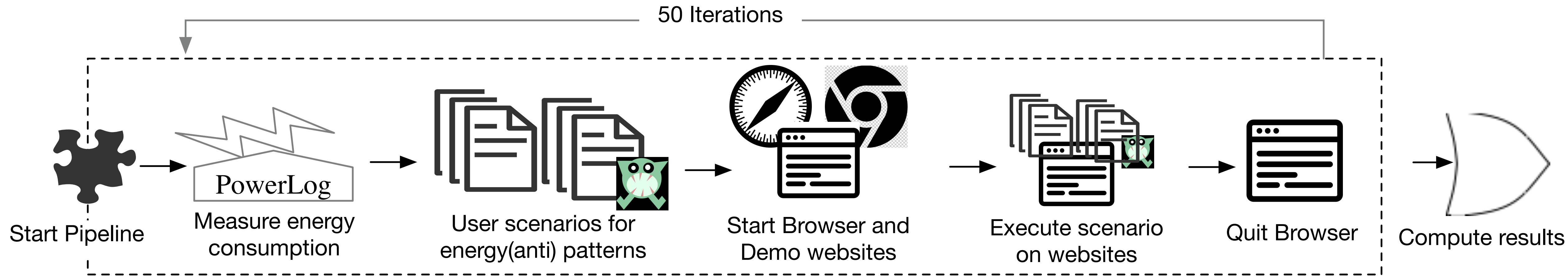
Paper

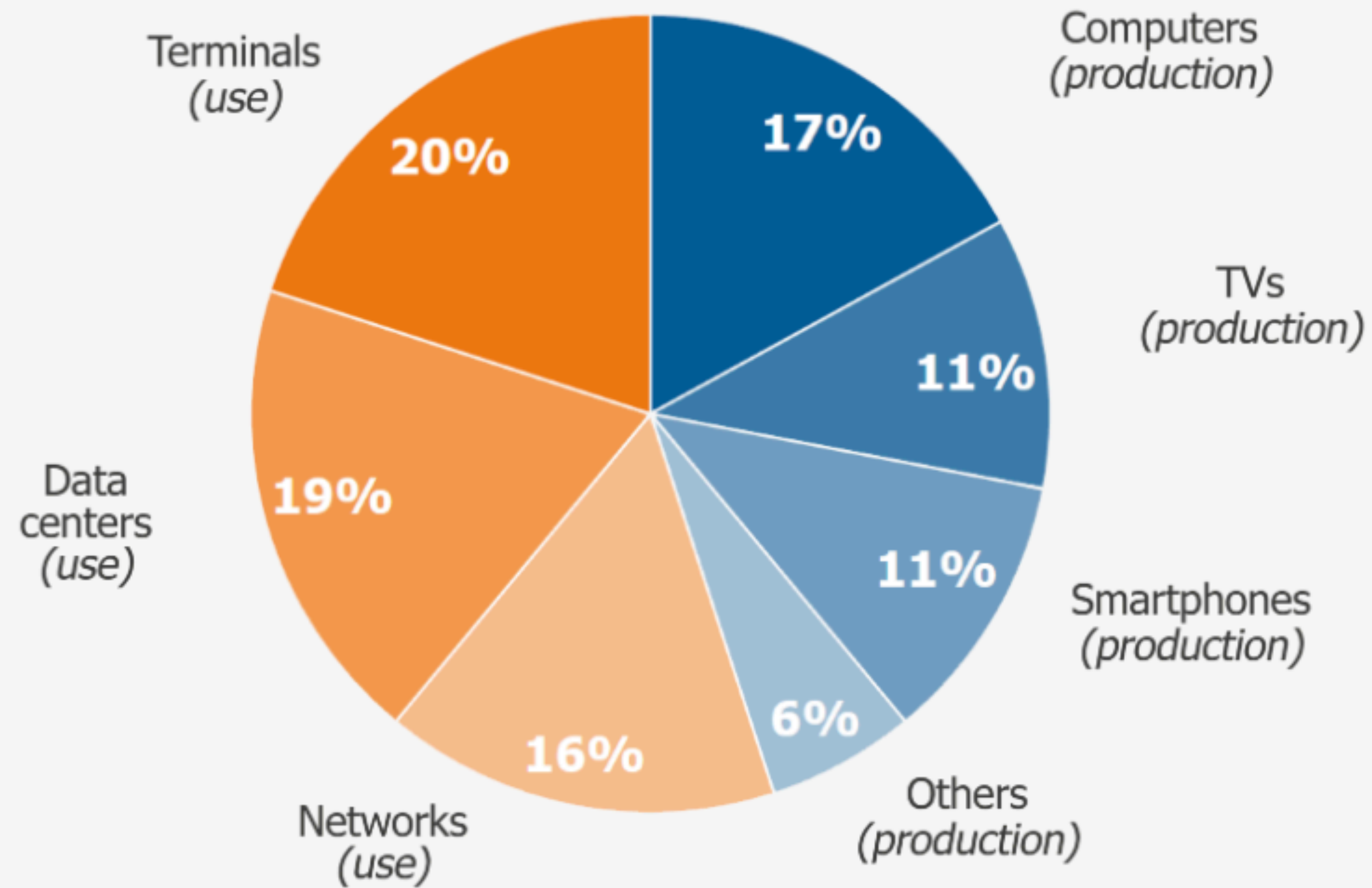
More Curious?

RQ2: Developers' Perception on Patterns



RQ3: Impact of Energy Patterns





Distribution of the energy consumption of digital technologies for production (45 %) and use (55 %) in 2017

[Source : Lean ICT, *The Shift Project* 2018]

Technologies disappear, software updates, increasing development costs due to technical debt, high-performance systems that need high power.

Saputri and Lee, 2021, Integrated framework for incorporating sustainability design in software engineering life-cycle: An empirical study