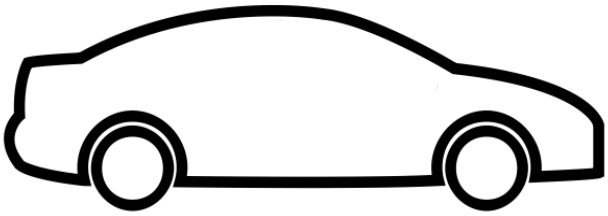
Vehicle Design Guide
(Please read before starting Part 2 of the survey)

Vehicle Buyers' Guide

An introduction to vehicle technologies

Thank you for completing Part 1 of the survey. This guide provides a more detailed **introduction to the vehicle technologies** we will be referring to in Part 2. **Please carefully review this information**, even if you feel you are already familiar with some of the details. We want to make sure you understand **the terminology we will be using in the survey.** You may refer back to this document as you complete Part 2.



This booklet is divided into the following sections:

INTRODUCTION

This guide will discuss vehicles that can be powered by gasoline only, electricity only, *both* electricity and gasoline, and hydrogen only. In particular, this guide focuses on **how these vehicles are powered**.

In Part 2 of the survey, you will be asked to share your thoughts on these different vehicle technologies, as well as to complete **"design games"** and **"choice exercises"** where you tell us **which vehicle would be ideal for you**.

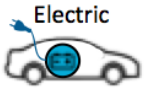
VEHICLE TECHNOLOGIES

The goal of this guide is to help you understand **how the following vehicle technologies differ** from one another and **how each can be recharged or refueled**. If there are any aspects of this information that you do not understand, please do not worry – further explanation will be available during Part 2 of the survey. While reading about these vehicle technologies, please consider the advantages and drawbacks of each in relation to your personal needs and desires.

The five vehicle technologies you will encounter in Part 2 of the survey are:

- A **conventional gasoline vehicle**, which uses **only gasoline** as its fuel.
- A **hybrid vehicle**, which, similar to a conventional vehicle, requires **only gasoline** input for refueling, but also uses a small, internally-recharged battery to reduce its fuel consumption. As such, this type of vehicle cannot be plugged in to recharge its small battery.
- A **plug-in hybrid vehicle**, which **can be plugged in to recharge** its medium-size battery, **and/or can run on gasoline**.
- A **battery electric vehicle**, which uses **only electricity** and so must be plugged in to recharge its large battery.
- A **hydrogen fuel cell vehicle**, which uses **only hydrogen** as its fuel.

The following table illustrates the differences among these five vehicle technologies:

Vehicle	Refuel or Recharge?			Mode of Operation
Drivetrain	Gasoline	Electricity	Hydrogen	
Conventional 	☑			• Uses only **gasoline** to power the engine.
Hybrid 	☑			• Is primarily powered by **gasoline**. However, a small battery and electric motor assist the engine to allow for greater fuel efficiency than a conventional gasoline vehicle. • Cannot be plugged in to recharge the battery.
Plug-in Hybrid 	☑	☑		• With a fully charged battery, the vehicle is powered by **electricity** for the first 16 to 110 kilometers. The vehicle then automatically switches to **gasoline.** Like a hybrid, when using gasoline, it has greater fuel efficiency than a conventional gasoline vehicle. • Must typically be plugged into a normal outlet or recharge station to recharge the battery.
Battery Electric 		☑		• Is powered solely by **electricity** for 80 to 450 kilometers. The battery can be recharged by plugging it into a normal outlet or recharge station. • Cannot use gasoline.
Hydrogen Fuel Cell 			☑	• Is powered solely by **hydrogen** fuel. A full tank can last for 300 to 550 kilometers.

VEHICLE FEATURES

The following section describes several **key features** of the vehicle technologies: **gasoline use**, **driving range, home recharging,** and **public recharging and refueling**. As you read the following section, please think about how these features are (or are not) compatible with your everyday life.

1. Gasoline Use

Conventional gasoline, hybrid, and **plug-in hybrid vehicles** can be refueled and powered by gasoline. Compared to a conventional gasoline vehicle, **hybrids** and **plug-in hybrids reduce gasoline use, resulting in increased fuel efficiency and thus reduced fuel costs**.

2. Driving Range

For **conventional vehicles**, the driving range is the distance the car can travel on a single, full tank of gasoline. For **electric vehicles**, the driving range (or "battery range") is the distance that the vehicle can travel on a fully charged battery. For **plug-in hybrid vehicles**, the total driving range is equal to the range of the gasoline engine plus the battery range, where vehicles with larger batteries have longer driving ranges. In Part 2 of the survey, some consumers may choose to upgrade to a larger battery for an additional cost to increase the vehicle's driving range.

For **hydrogen fuel cell vehicles**, the driving range is the distance that the vehicle can travel on a full tank of hydrogen. In Part 2 of the survey, some consumers may choose to upgrade to a larger tank for an additional cost to increase the vehicle's driving range.

The figure below compares some examples of the driving ranges of conventional gasoline, hybrid, plug-in hybrid, electric, and hydrogen fuel cell vehicles:

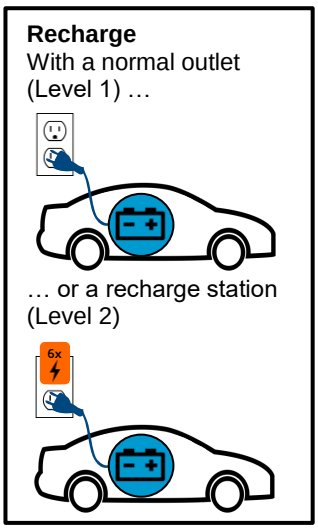
Vehicle	Driving Range	Description
Drivetrain	Gasoline range → Electric range → Hydrogen range →	
Conventional	550 km range	An average conventional vehicle can drive about 550 kilometers on one tank of gas.
Hybrid	800 km range	A hybrid can travel further on one tank of gas compared to a conventional vehicle due to the assistance of a small battery.
Plug-in hybrid	50 km electric range, then automatically switches to gas	Plug-in hybrids can run primarily on electricity for a specified range, depending on the size of their electric battery. Once the battery is depleted, the vehicle can run on gasoline stored in its fuel tank. The total driving range is similar to that of a hybrid vehicle.
Plug-in hybrid	110 km electric range, then automatically switches to gas	
Electric	140 km electric range	Electric vehicles run only on battery power. The battery is charged by plugging the vehicle in to an electricity source. The driving range of an electric vehicle varies by the size of the battery.
Electric	300 km electric range	
Hydrogen	500 km range	The range of a hydrogen fuel cell vehicle depends on the fuel tank size, like a conventional gasoline vehicle.

3. Home Recharging

Plug-in hybrid and electric vehicles can both operate using electricity, and so you may be able to charge these vehicles at home if you have regular access to a parking spot that is close to an electrical outlet. The charging time depends on the vehicle's battery size as well as whether you can access a normal outlet (**Level 1 charging**) or a home recharge station (**Level 2 charging**).

- **Normal outlet (Level 1)**:
  Normal 120-volt electrical outlets are the same type you may use to charge your cell phone or laptop. You may find such an outlet in your home garage, on the side of your house, or in your parking lot.

- **Recharge station (Level 2)**:
  This type of outlet is designed for charging plug-in hybrid and electric vehicles. It can recharge a vehicle up to **six times faster** than a normal (Level 1) outlet. For this reason, many plug-in hybrid and electric vehicle drivers choose to install a Level 2 recharge station at home for about $750-$2000, although such installation requires a 240-volt outlet (e.g., that which a dryer plugs into) near their parking spot.



4. Recharging Outside of the Home

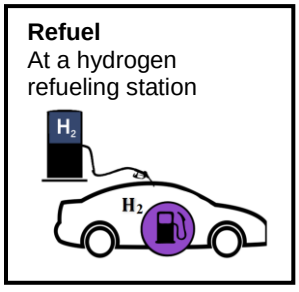
Plug-in hybrid and electric vehicles can also be charged in public areas outside of your home (e.g., at shopping centers, parking lots, schools, and workplaces) by **"destination chargers."** Destination charging stations are **similar to Level 2 home recharge stations, which are much faster than normal Level 1 outlets.** You may have noticed some of these charging stations in areas where you typically park. Many of these destination Level 2 charging stations are currently free to use, but some require drivers to pay a user fee or join a service to use the station.

A special subset of destination chargers, known as **"DC fast chargers,"** are **even faster than Level 2 recharge stations and can recharge an almost-empty battery in about 30 minutes** (compared to a Level 2 charger, which can take up to 8 hours. In the future, DC fast chargers may be located at regular intervals along major highways and travel routes to allow drivers to quickly recharge their electric vehicles when traveling long distances.

5. Hydrogen Refueling

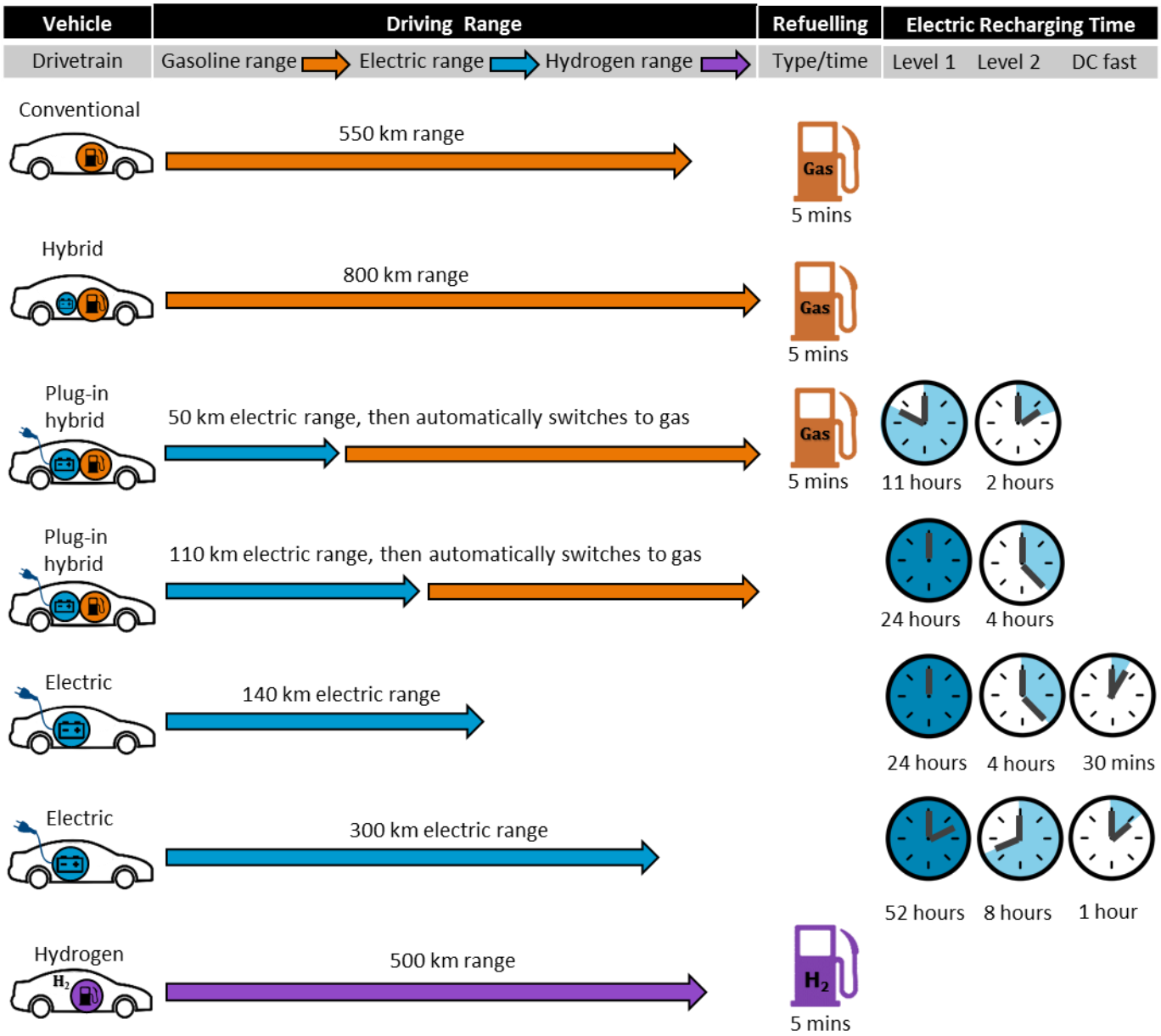
Hydrogen fuel cell vehicles are fueled by hydrogen, which is pumped into the vehicle in a similar way as gasoline. The hydrogen is converted into electricity inside the vehicle, which is then used to power an electric motor. These vehicles must be refueled at designated **hydrogen refueling stations**:

- **Hydrogen refueling stations** are designed specifically for **refueling hydrogen fuel cell vehicles** and take about the same time as it does to refuel a conventional gasoline or hybrid vehicle.



6. Vehicle Summary

The figure below summarizes some key features of the five vehicle technologies presented in this guide, including driving range and refueling or recharging time (for Level 1, Level 2, and DC fast charging stations). Note that recharge time refers to the time it takes to recharge an empty battery; however, most drivers do not usually deplete their vehicle batteries completely.



COMMONLY ASKED QUESTIONS

Commonly Asked Questions about Driving with ***Electricity***

1. **How long does it take to recharge a plug-in hybrid or electric vehicle?**
   Recharging time depends on vehicle size and battery range, as well as the voltage of the charger. Vehicles with a greater electric range need larger batteries and, therefore, take longer to recharge. In addition, outlets with a higher voltage (e.g., Level 2 vs. Level 1 outlets, or DC fast chargers vs. Level 2 outlets) reduce charging times.

2. **Can I partially charge the battery?**
   Yes. Just like refueling a gas tank, you can recharge your battery part way if you wish. However, batteries do not charge in a linear way, meaning that if it takes 4 hours to fully recharge a battery, charging it for 1 hour will charge it more than 25%.

3. **What are some advantages of driving with electricity compared to gasoline?**
   It depends on your priorities and interests. Electricity is generally cheaper than gasoline, costing roughly 50-70% less per kilometer in most Canadian regions. Driving with electricity also tends to produce less urban air pollution and greenhouse gas emissions than driving with gasoline – even including emissions from electric power plants. The size of these reductions depends on the electricity source (e.g., coal- vs. wind-generated electricity).

Commonly Asked Questions about Driving with ***Hydrogen***

1. **Where does the hydrogen come from?**
   Although hydrogen exists naturally, it must first be extracted and processed before it can be used as fuel. Hydrogen is most commonly collected from natural gas, but it can also be extracted from oil, biomass, or water. Like electricity, hydrogen fuel can be produced from renewable sources (e.g., wind power) or non-renewable sources (e.g., coal power).

2. **What are some advantages of driving with hydrogen compared to gasoline?**
   It depends on your priorities and interests. Driving with hydrogen usually produces less air pollution and greenhouse gas emissions than driving with gasoline – even when the hydrogen is made from fossil fuels and other non-renewable electricity sources. Hydrogen fuel cell vehicles emit only water vapor from their tailpipe. Although the cost of hydrogen differs depending on how it is produced, it generally costs about the same as gasoline, per kilometer driven. Also, hydrogen can be produced in small facilities close to refueling stations and so, unlike gasoline, it may not have to be imported and transported long distances.

3. **Is hydrogen safe?**
   Hydrogen fuel cell vehicles are thought to be as safe as conventional gasoline vehicles given that they carry compressed hydrogen in very strong tanks, which have not leaked in simulated crashes. Also, because hydrogen fuel is quite light, the gas would rise quickly in the event of a leak without leaving behind a pool of liquid fuel like a gasoline tank leak might.

4. How can you refuel a hydrogen fuel cell vehicle?

Hydrogen fuel cell vehicles are refueled at a designated station using a pump, much like regular gasoline vehicles. As such, it takes about as long to refuel a hydrogen fuel cell vehicle as it does to refuel a conventional gasoline vehicle. Initially, not all gas stations will carry hydrogen fuel; however, in the future it is possible that some gas stations may offer hydrogen alongside gasoline and diesel. In a few years, hydrogen fuel may also be sold on its own at designated hydrogen refueling stations.

GETTING READY FOR PART 2

In Part 2, we will be asking you questions about the vehicle technologies and features discussed in this guide. These questions will help us to develop an understanding of which vehicle technology you may choose to purchase/lease in the future.

First, you will be asked to complete a series of **design exercises** where you will **design your ideal next vehicle** based on your current budget, vehicle preferences, and driving needs. Before beginning the design exercises, you will first select the make and model of the next vehicle you plan to purchase/lease. Then, you will be able to convert that vehicle into any of the vehicle technologies described in this guide, if you wish, as well as to customize the following features:

1. **Driving range** - you may select your desired battery range for plug-in hybrid and electric vehicles, as well as your desired driving range for hydrogen fuel cell vehicles.
2. **Home recharging access** - you may also choose to install a home recharger for plug-in hybrid and electric vehicles.

These customizations will have associated costs, which will be shown as you design your ideal vehicle. For example, an electric vehicle with a 350 km driving range will cost more than an electric vehicle with a 100 km driving range. Please **keep your budget in mind** when designing and customizing your ideal vehicle.

In the initial design exercises, you can design your ideal next vehicle with any of the vehicle technologies described in this guide. However, because some vehicle technologies are not currently available in certain sizes and styles, you may be asked to redesign your vehicle in later exercises. In doing so, you may have to choose between keeping a certain size of vehicle or keeping a certain type of vehicle technology. Additionally, you will be asked to complete design games with higher and lower vehicle costs.

For example, your design exercise may look like this:

You will complete *up to* 4 design games

- In the first game, you can design any vehicle type with any vehicle technology.
- In the second game, you may have to rethink your design if your first design is not currently available in Canada.
- You will also complete games where the **prices will be cheaper**.

You can change and upgrade the vehicle features

- To design the vehicle that you would like to buy, please investigate the upgrades available in the drop-down menus.
- Be sure to select **both** electric range and recharge time for **plug-in hybrid** and **electric vehicles,** and only hydrogen range for **hydrogen fuel cell vehicles**

Recharge times are personalized to you

- Here you will see the recharge times based on the recharge access that you have said you have available at home.
- This is based on your responses in Part 1 of the survey.

Vehicle Design 1 of 4

Vehicle type	Driving range	Gasoline fuel use	Refuel/ Home recharge time	Purchase price	I CHOOSE
	→	⛽	🕐	$	
A **conventional** Honda CIVIC	**650 km** gasoline	**6.16** L/100 km	5 mins	**$ 25,000**	Conventional
A **hybrid** Honda CIVIC	**1,050 km** gasoline	**4.12** L/100 km	5 mins	**$ 26,380**	Hybrid (2nd Choice)
A **plug-in hybrid** Honda CIVIC	Electric for the first: 32km (+$2,680)	**4.12** L/100 km	Level 2: 0.9 hrs (+ $2,500)	**$ 30,180**	Plug-in hybrid (1st Choice)
An **electric only** Honda CIVIC	Electric only for: 200km (+$13,820)	None	Level 1: 32.5 hrs (+ $0)	**$ 38,820**	Electric
A **hydrogen fuel cell** Honda CIVIC	Hydrogen only for: 600km (+$16,230)	None	5 mins	**$ 41,230**	Hydrogen

Click HERE to access the Vehicle Buyers' Guide

Next

The vehicle technologies

- These are explained in full in your Vehicle Buyers' Guide.

You can select your ideal driving range

- If you would like a vehicle that uses electricity, you can select the battery range (in kilometers).
- If you would like a vehicle that uses hydrogen, you can select the driving range (in kilometers).
- The cost of the upgrade is shown in the drop-down menu.

The next button

- When your selections are complete, click "next" to lock in your choices. This will take you to the next design game.

Your first and second choice

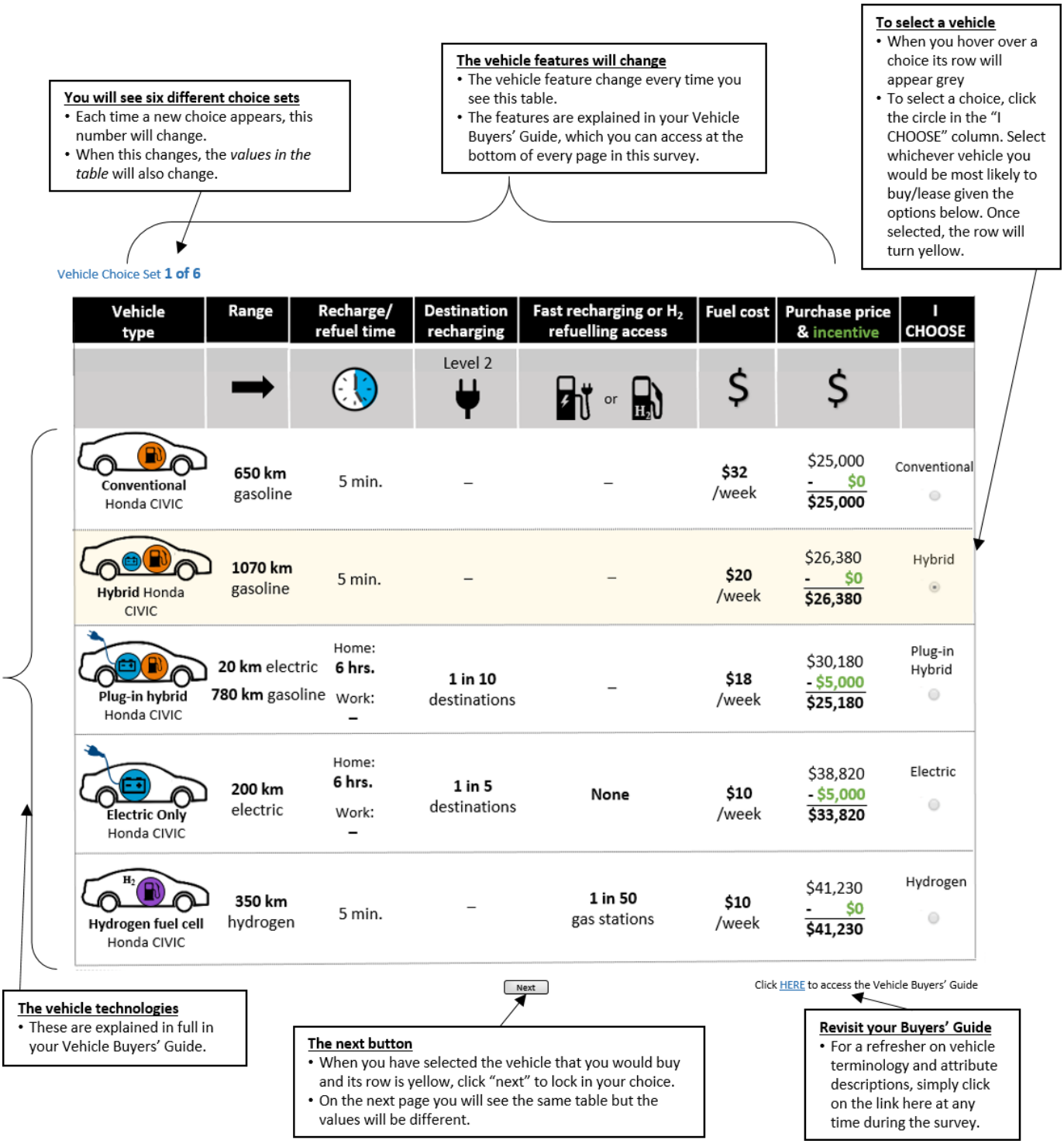
- Once you have customized your selections, please select one vehicle to be your **first choice** and another vehicle to be your **second choice** in the drop-down menus in the "I CHOOSE" column.
- Your first choice will become highlighted in bright yellow, and your second choice will be highlighted in a paler yellow.
- Please leave the remaining drop-down menus in this column blank if they are not your first or second choice.

In Part 2, you will also be asked to complete a series of **six choice exercises.** You will be presented with different versions of the make and model of your likely next vehicle purchase/lease that you indicated at the start of the design game, with the following *varying* features:

1. **Vehicle technology –** the five different vehicle technologies presented in this guide (i.e., conventional gasoline, hybrid, plug-in hybrid, electric, and hydrogen fuel cell vehicle)
2. **Purchase price –** the price of each vehicle type will change based on the vehicle technology
3. **Point-of-sale incentive** – a government-funded subsidy for plug-in hybrid, electric, and hydrogen fuel cell vehicles may be $0, $5000, or $10000
4. **Weekly fuel cost –** the weekly cost of fuel for each vehicle type will vary depending on your stated current fuel costs
5. **Driving range –** the number of kilometers possible to drive on a fully charged battery or full tank of gasoline or hydrogen
6. **Home recharging time –** the time required (in hours) to charge a plug-in hybrid and electric vehicle at your home will vary depending on the battery's range and the type of charger used (i.e., charging with a Level 1 or Level 2 charger)
7. **Work recharging time –** the time required (in hours) to charge a plug-in hybrid and electric vehicle at your workplace will vary depending on the battery's range and the type of charger used (i.e., charging with a Level 1 or Level 2 charger)
8. **Destination recharging and refueling access –** the percentage of your destinations that have recharging stations (Level 2 charging) for plug-in hybrid and electric vehicles, as well as the percentage of gas stations that have hydrogen for hydrogen fuel cell vehicles
9. **Access to DC fast charging –** for plug-in hybrid and electric vehicles, the presence or absence of DC fast chargers on major highways will differ.

After reviewing the vehicle features presented to you, you will be asked to choose which version of your next intended vehicle purchase/lease you most prefer, based on your vehicle preferences, driving needs and budget. Note that we will ask you to assume that the vehicles are all the same (e.g., with respect to performance, comfort, and style), except for the features presented.

For example, you may see a choice set that looks like this:



In Part 2 of the survey, we will refer to the features and vehicle technologies discussed in this guide. If you do not understand any of the information outlined in this guide, please do not worry as you will have the option to consult this guide again throughout Part 2.

Thank you for reading this guide.
We look forward to your responses in Part 2!