

Energy Efficient routing with OSM

- reach your destination fast AND eco -

SOTM 2018 – Milan – 30.7.2018

- Dr. Arndt Brenschede -

B(ike?)Router ?

- 01 / 2013 Initial release „BRouter“
-
- 01 / 2014 first, experimental car routing
-
- 05 / 2016 turning instructions
- 12 / 2016 turn restrictions
- 09 / 2017 kinematic model
- 10 / 2017 Map-QA road network



Usable car routing

Status Quo

- Market is dominated by motorway-centric routing, optimizing travel-time only
- Example: Stuttgart → Luxemburg (Router: OSRM), **Northern suburb**

351 km **Time: 3h 26m**

OpenStreetMap Bearbeiten Chronik Export Mehr Anmelden Registrieren

48.7204, 9.1475
49.629, 6.158
Auto (OSRM) Los

Routenanweisungen:
Distanz: 351km. Zeit: 3:26.

1. Starten beim Ende von **Koboldweg** 40m
2. Rechts abbiegen auf **Dornröschenweg** 200m
3. Links abbiegen auf **Hechinger Straße** 200m
4. Rechts abbiegen auf **Heilbrunnenstraße** 400m
5. Am Straßenende links abbiegen auf **Nord-Süd-Straße** 900m
6. Bei der Auffahrt links abbiegen auf

© OpenStreetMap-Mitwirkende ♥ Spenden

Status Quo

- Market is dominated by motorway-centric routing optimizing travel.
- Example: Stuttgart → Luxemburg (Router: OSRM), **City center**

313 km Time: 3h 25m (-38km, same travel time)

The screenshot shows the OpenStreetMap interface with a route from Stuttgart to Luxembourg. The route is highlighted in blue and passes through Saarbrücken, Kaiserslautern, Mannheim, and Heidelberg. The map includes a scale bar (30 km / 20 mi) and a copyright notice for OpenStreetMap-Mitwirkende.

OpenStreetMap Bearbeiten Chronik Export Mehr Anmelden Registrieren

48.7204, 9.1475
49.618, 6.152
Auto (OSRM) Los

Routenanweisungen:
Distanz: 313km. Zeit: 3:25.

1. Starten beim Ende von **Koboldweg** 40m
2. Rechts abbiegen auf **Dornröschenweg** 200m
3. Links abbiegen auf **Hechinger Straße** 200m
4. Rechts abbiegen auf **Heilbrunnenstraße** 400m
5. Am Straßenende links abbiegen auf **Nord-Süd-Straße** 900m
6. Bei der Auffahrt links abbiegen auf 470m

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Cost-Function in Routing:

$$\textit{Cost} = \textit{Time}$$

Cost-Function in Energy Efficient Routing:

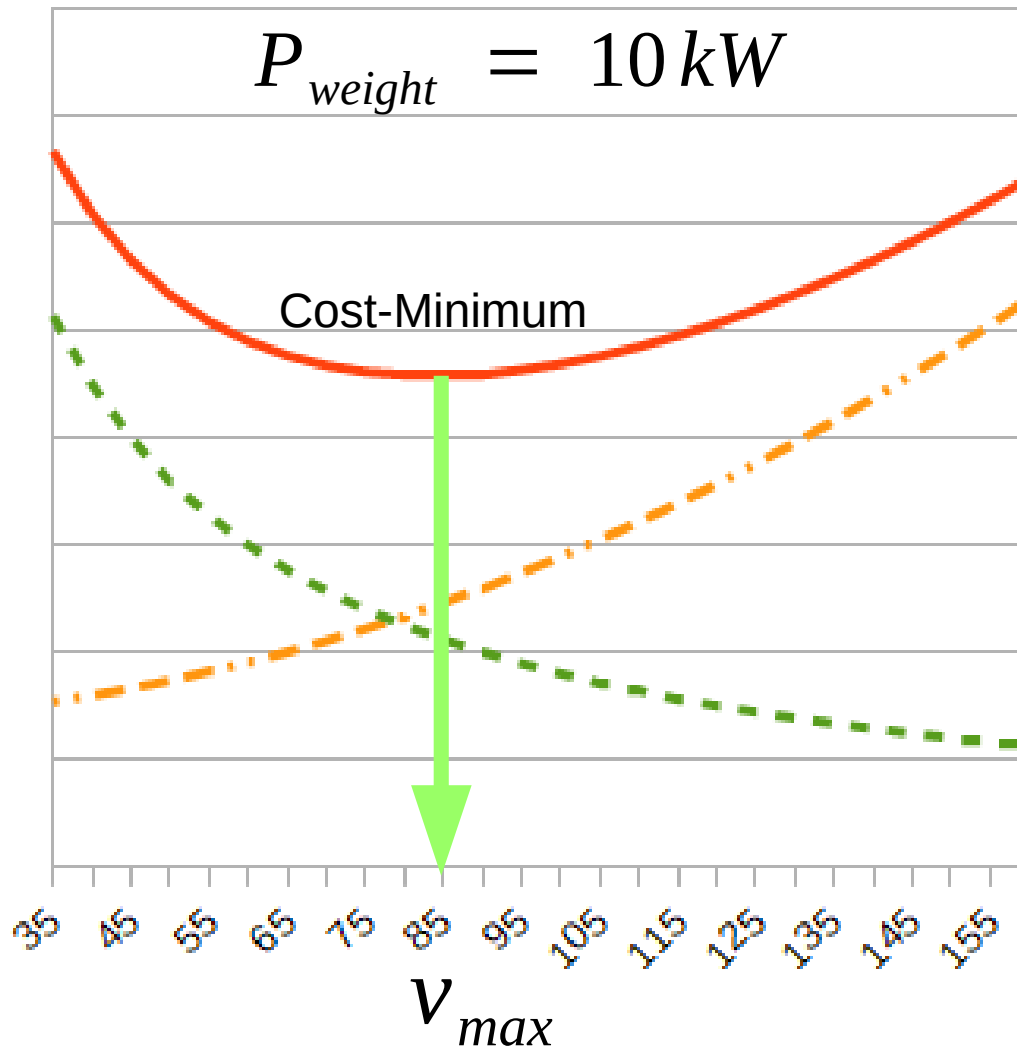
$$Cost = Time + \frac{Energy}{P_{weight}}$$

P_{weight} = Weighting Power (measured in kW)

Specify Energy Preference: 2 Options

V-max (km/h)	P-weight (kW)	
61	3,7	
89	11	
110	22	
120	28,6	
144	50	

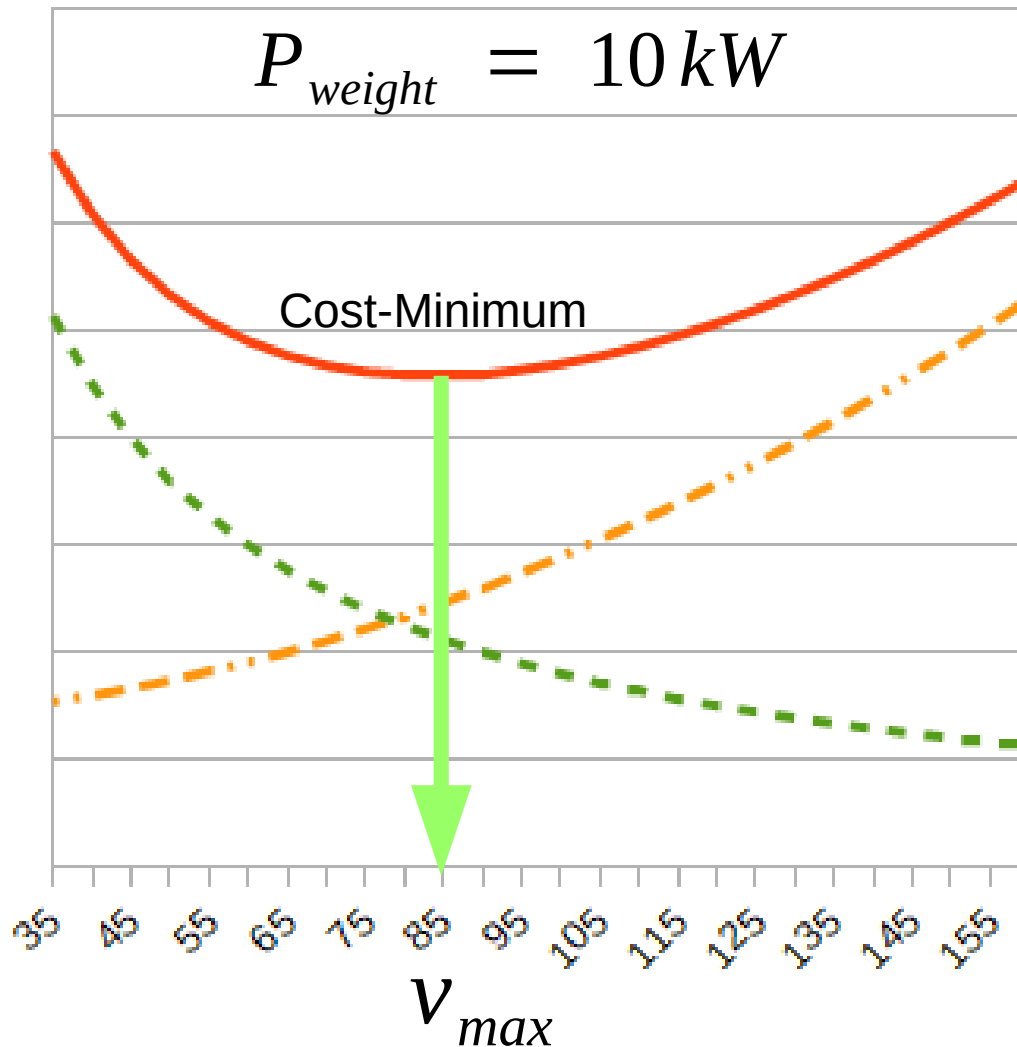
Equivalence of $P(\text{weight})$ und $v(\text{max})$!



$$\text{Cost} = \text{Time} + \frac{\text{Energy}}{P_{\text{weight}}}$$

- Energy-Part
- Time-Part
- Total

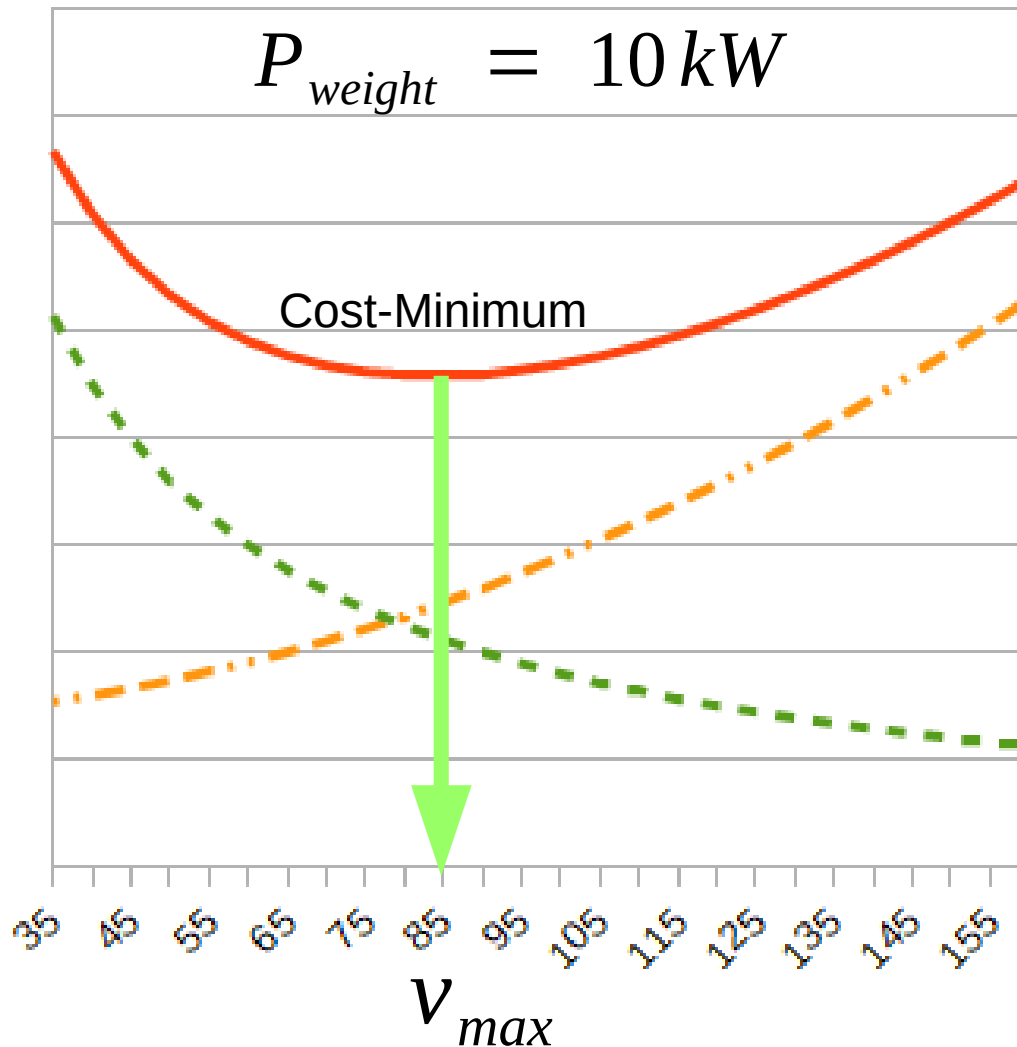
Equivalence of $P(\text{weight})$ und $v(\text{max})$!



$$\text{Cost} = \text{Time} + \frac{\text{Energy}}{P_{\text{weight}}}$$

→ $P_{\text{weight}} = c_w * A * \rho * v_{\text{max}}^3 - P_{\text{aux}}$

Equivalence of $P(\text{weight})$ und $v(\text{max})$!



Entropy

$$\text{Cost} = \text{Time} + \frac{\text{Energy}}{P_{\text{weight}}}$$

→ $P_{\text{weight}} = c_w * A * \rho * v_{\text{max}}^3 - P_{\text{aux}}$

Routing depending on Energy-Preference

Aschaffenburg → Bensheim **Vmax = 160 km/h** =====> 52 Minutes, 23 kWh

BRouter-Web 0.6.3
'esc' or 'q' to disable drawing, 'd' to enable drawing
Web client for BRouter · work in progress · about

Options
Profile:
Alternative:

Route
Length: 92.8 km
Time: 52.5 min
Energy: 23.17 kWh (mean: 24.96)
Ascent: 93 m (plain: -21)
Cost: 116552 (mean: 1.26)

Download [GPX](#) · [KML](#) · [GeoJSON](#) · [data CSV](#)

Profile Data

```
# kinematic parameters|
assign vmax = 160 # kmh
assign recup_efficiency = 0.7 # (ratio)
assign totalweight = 1640 # kg
assign f_roll = 232 # Newton
assign f_air = 0.4 # 0.5*cw*A*rho
assign f_recup = 400 # Newton
assign p_standby = 280 # Watt
```

5 km 5 mi

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Routing depending on Energy-Preference

Aschaffenburg → Bensheim **Vmax = 120 km/h** =====> 72 Minutes, 9 kWh

BRouter-Web 0.6.3
'esc' or 'q' to disable drawing, 'd' to enable drawing
Web client for BRouter · work in progress · about

Options
Profile: <custom>
Alternative: original

Route
Length: 65.2 km
Time: 71.8 min
Energy: 9.2 kWh (mean: 14.11)
Ascent: 148 m (plain: -21)
Cost: 101679 (mean: 1.56)

Download GPX · KML · GeoJSON · data CSV

Profile Data

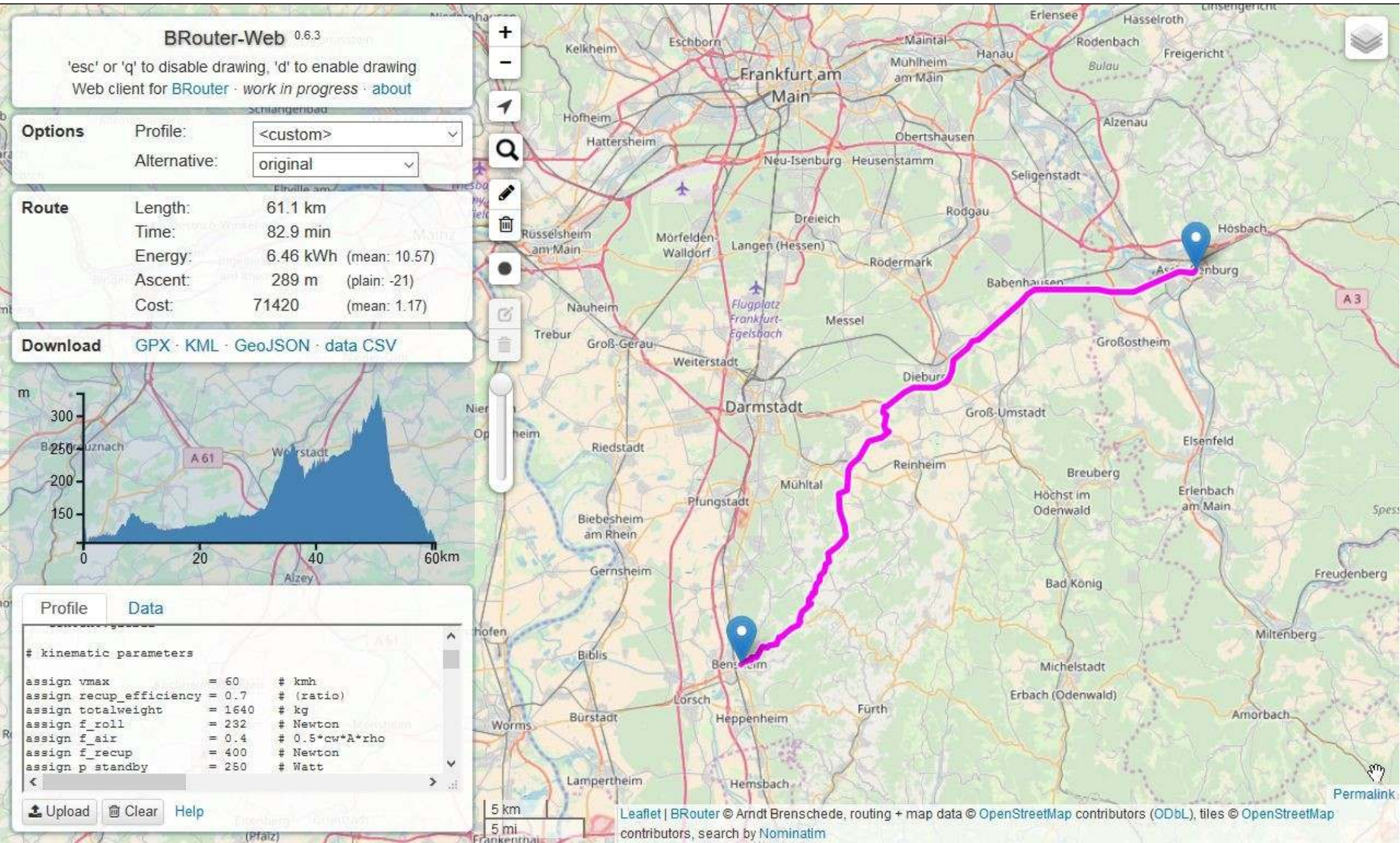
```
# kinematic parameters
assign vmax = 120 # kmh
assign recup_efficiency = 0.7 # (ratio)
assign totalweight = 1640 # kg
assign f_roll = 232 # Newton
assign f_air = 0.4 # 0.5*cw*A*rho
assign f_recup = 400 # Newton
assign p_standby = 250 # Watt
```

5 km 5 mi

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Routing depending on Energy-Preference

Aschaffenburg → Bensheim **Vmax = 60 km/h** =====> 83 Minutes, 6,5 kWh



Routing depending on Energy-Preference

Aschaffenburg → Bensheim **Vmax = 60 km/h** =====> 83 Minutes, 6,5 kWh

The screenshot displays the BRouter-Web interface for a route from Aschaffenburg to Bensheim. The route is highlighted in pink on a map of the region. The interface includes a sidebar with navigation controls, a route information panel, a download section, an elevation profile, and a kinematic parameters section.

BRouter-Web 0.6.3
'esc' or 'q' to disable drawing, 'd' to enable drawing
Web client for BRouter · work in progress · about

Options
Profile: <custom>
Alternative: original

Route
Length: 64.1 km
Time: 82.9 min
Energy: 6.46 kWh (mean: 10.57)
Ascend: 289 m (plain: -21)
Cost: 71420 (mean: 1.17)

Download GPX · KML · GeoJSON · data CSV

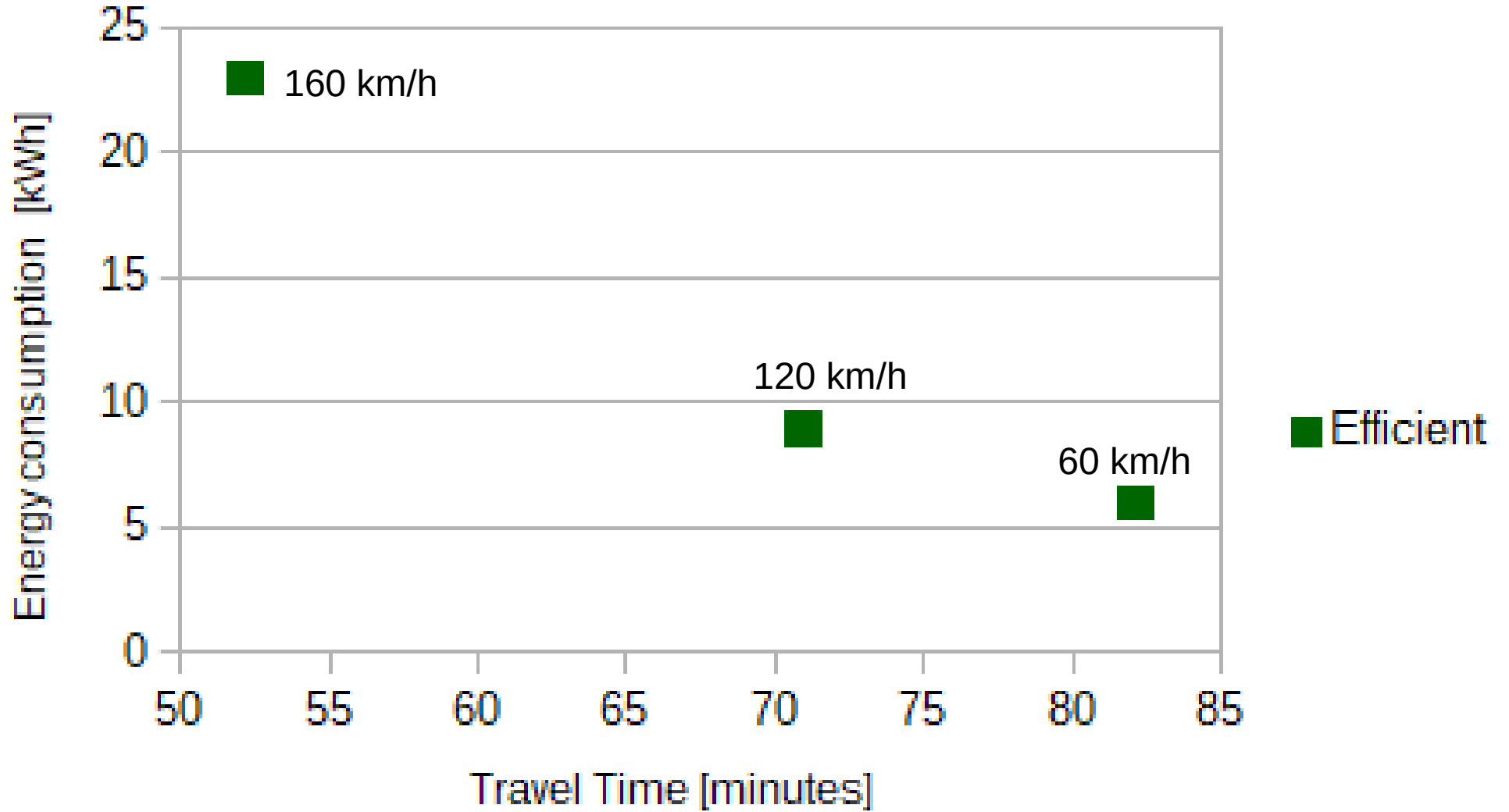
Elevation Profile
The profile shows elevation in meters (m) on the y-axis (0 to 300) and distance in kilometers (km) on the x-axis (0 to 60). The route starts at approximately 150m, rises to a peak of about 300m near Würzburg, and then descends to around 100m near Bensheim.

Profile Data

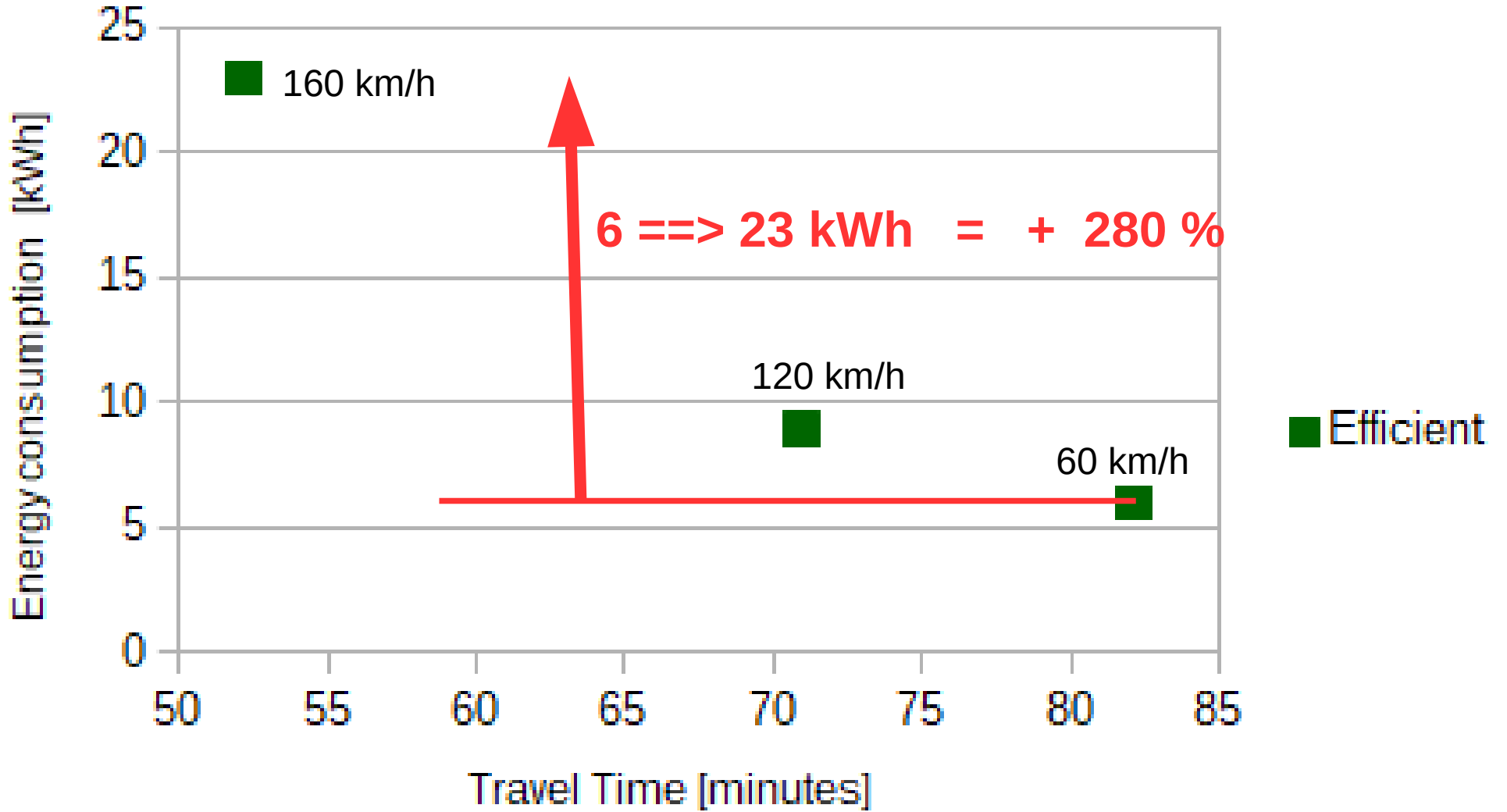
```
# kinematic parameters
assign vmax = 60 # kmh
assign recup_efficiency = 0.7 # (ratio)
assign totalweight = 1640 # kg
assign f_roll = 232 # Newton
assign f_air = 0.4 # 0.5*cw*A*rho
assign f_recup = 400 # Newton
assign p_standby = 250 # Watt
```

5 km 5 mi
Leaflet | BRouter © Arndt Brenschede, routing + map data © OpenStreetMap contributors (ODbL), tiles © OpenStreetMap contributors, search by Nominatim

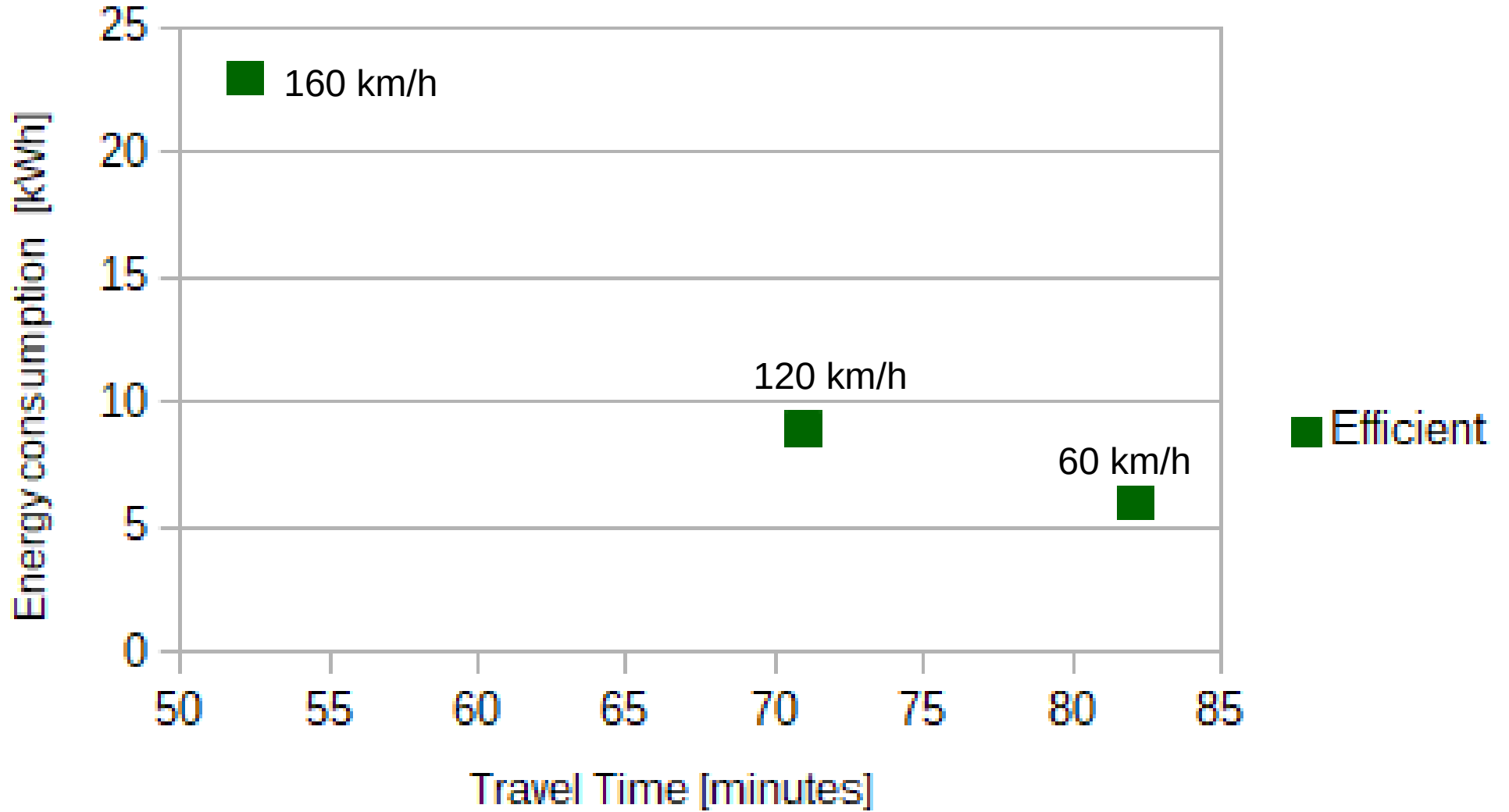
Energy – Time Diagram



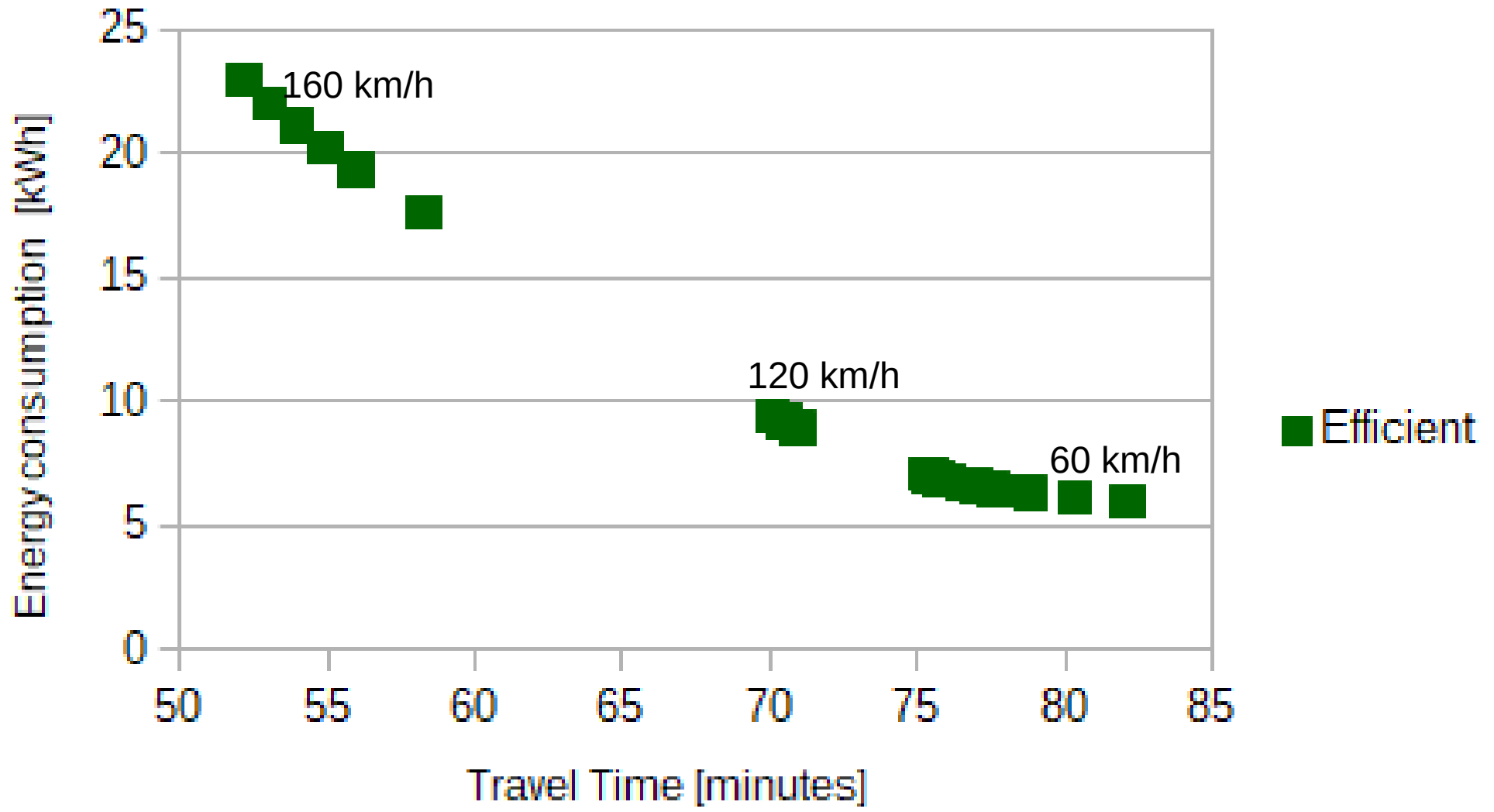
Energy – Time Diagram



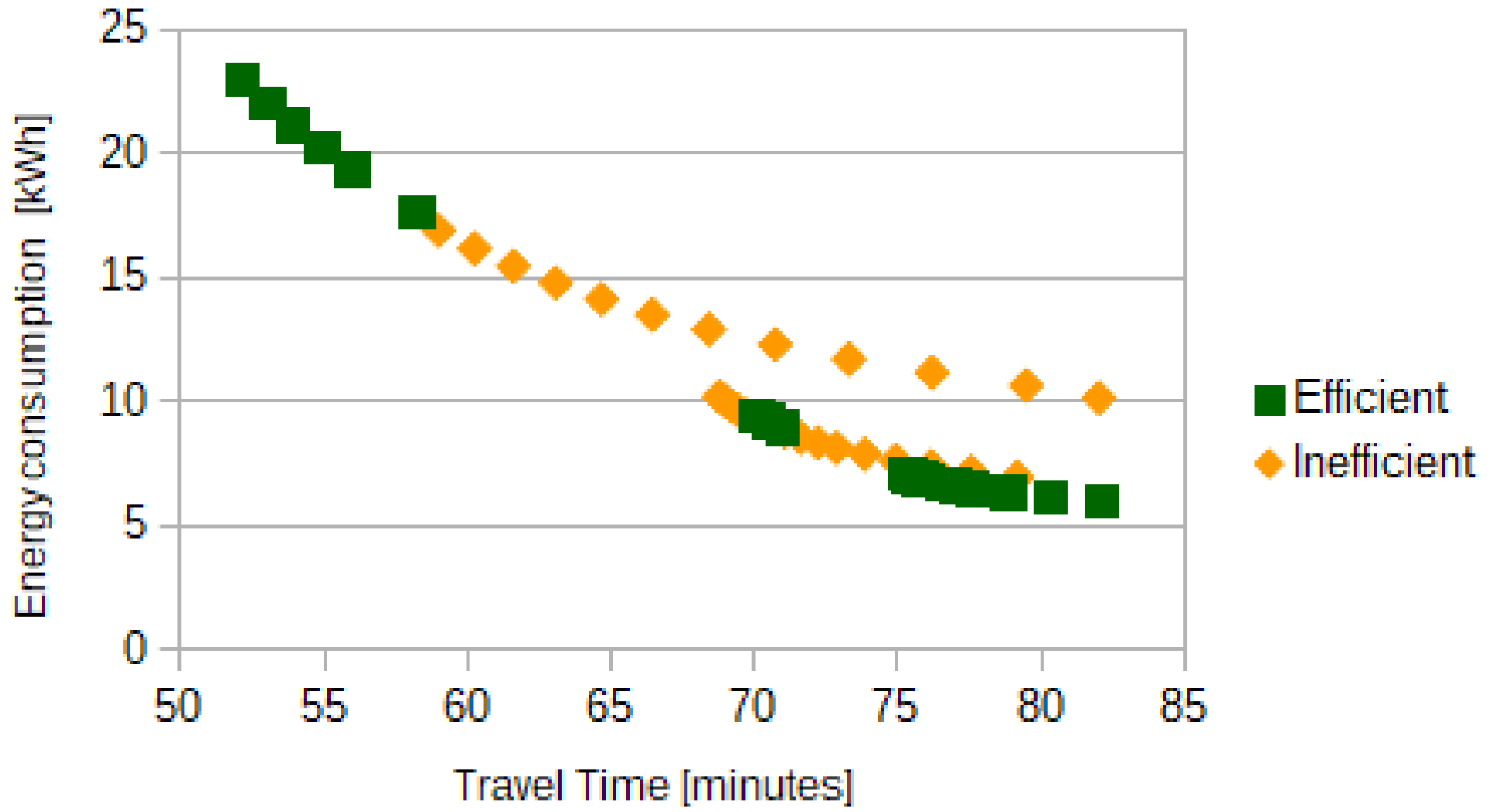
Energy – Time Diagram



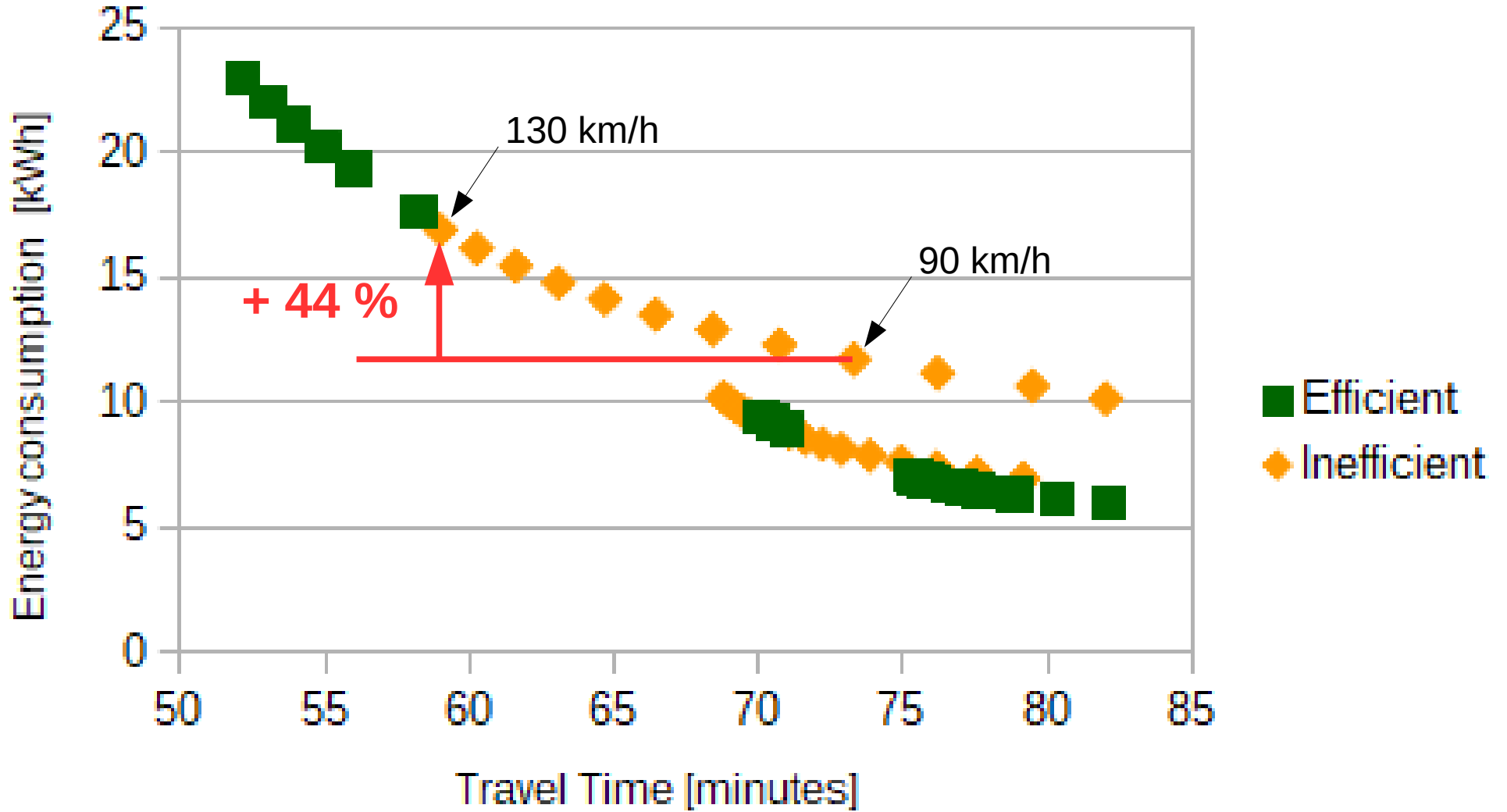
Energy – Time Diagram



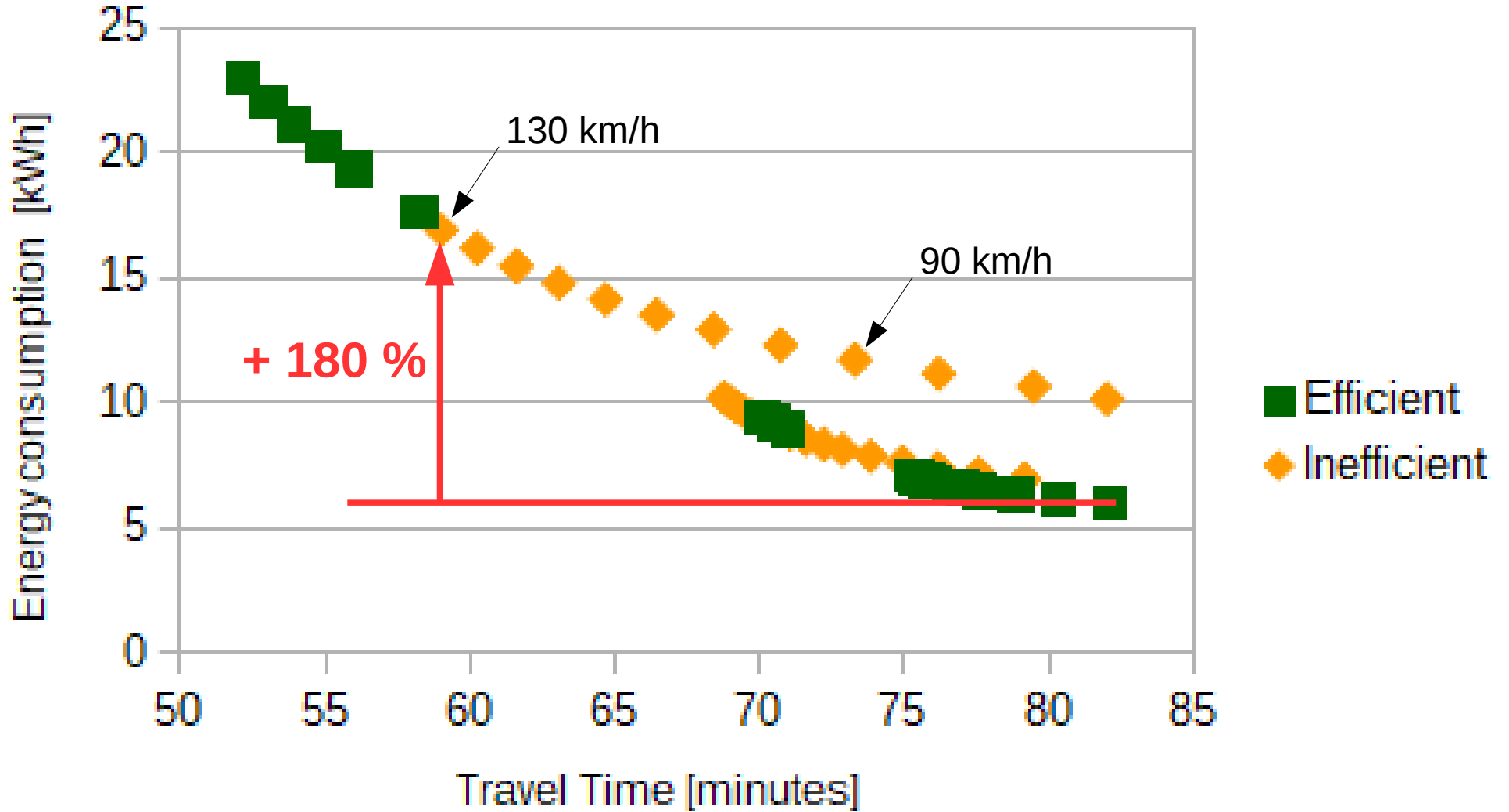
Energy – Time Diagram



Energy – Time Diagram

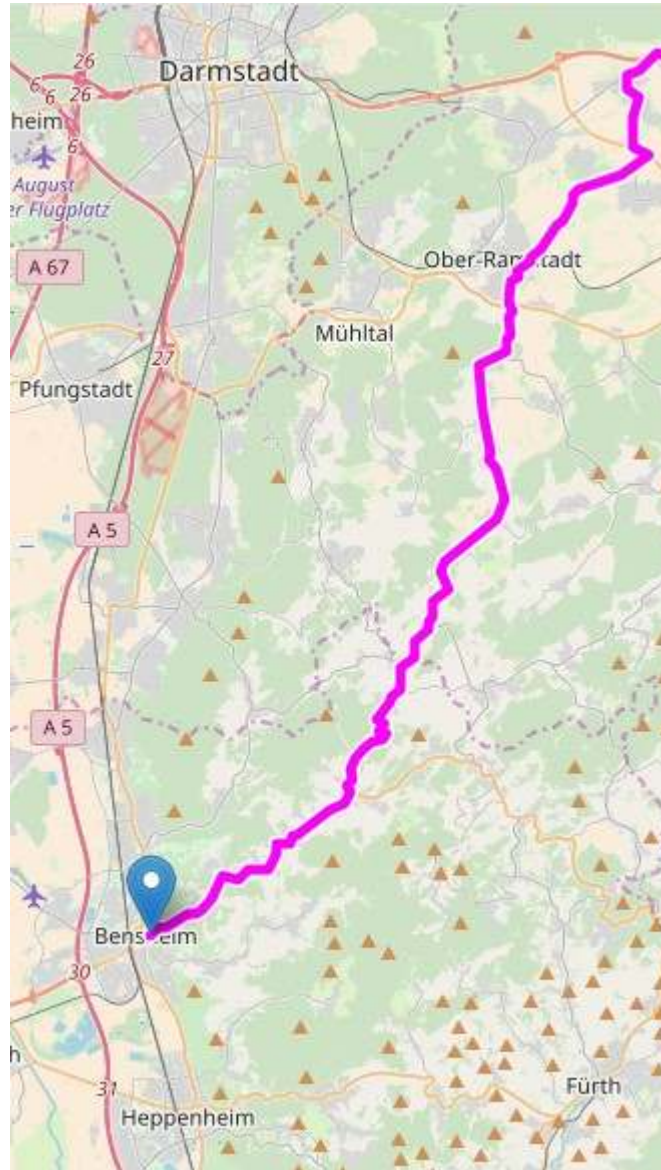


Energy – Time Diagram

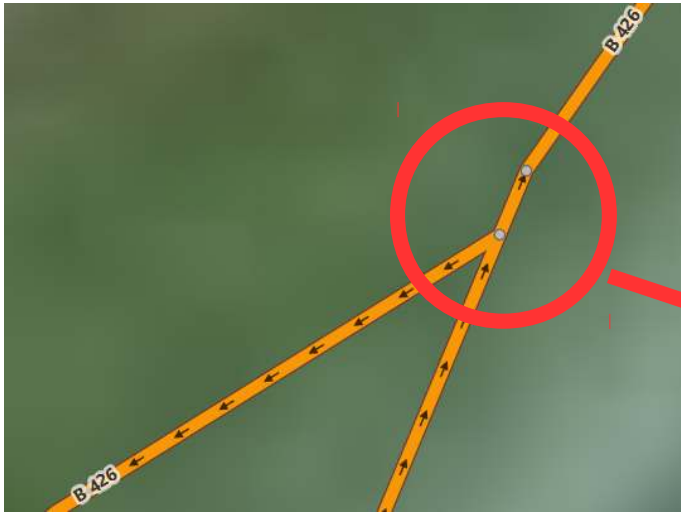


Should I ? Really ?

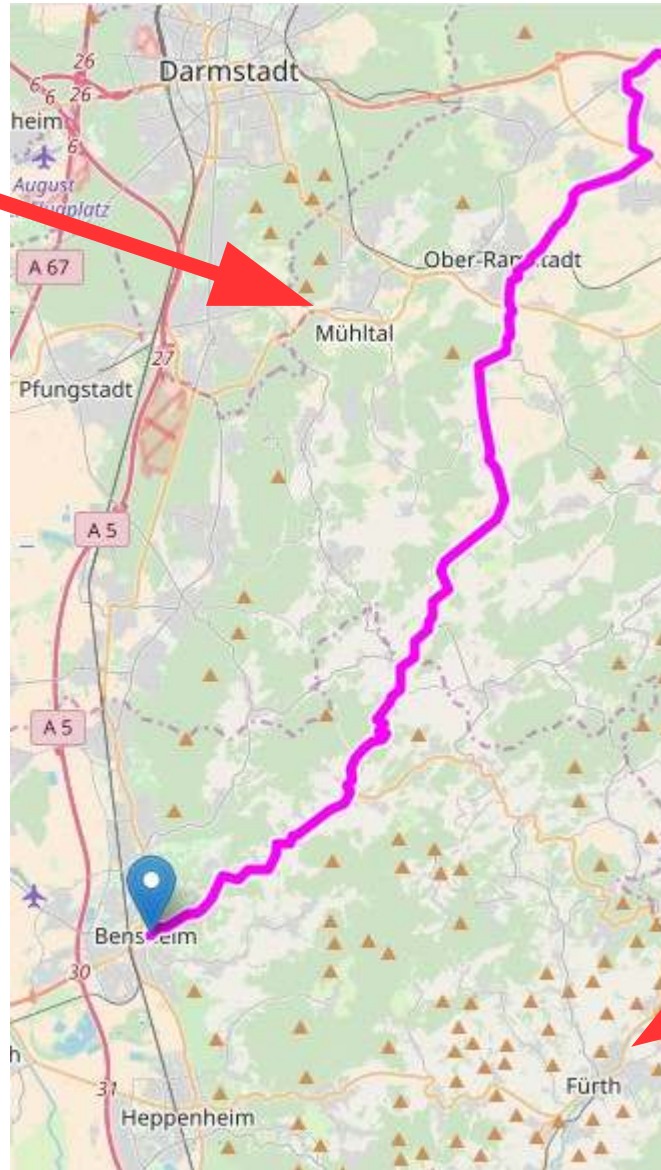
- travelling on minor roads needs high quality maps -



Connectivity? Status Quo 09/2017



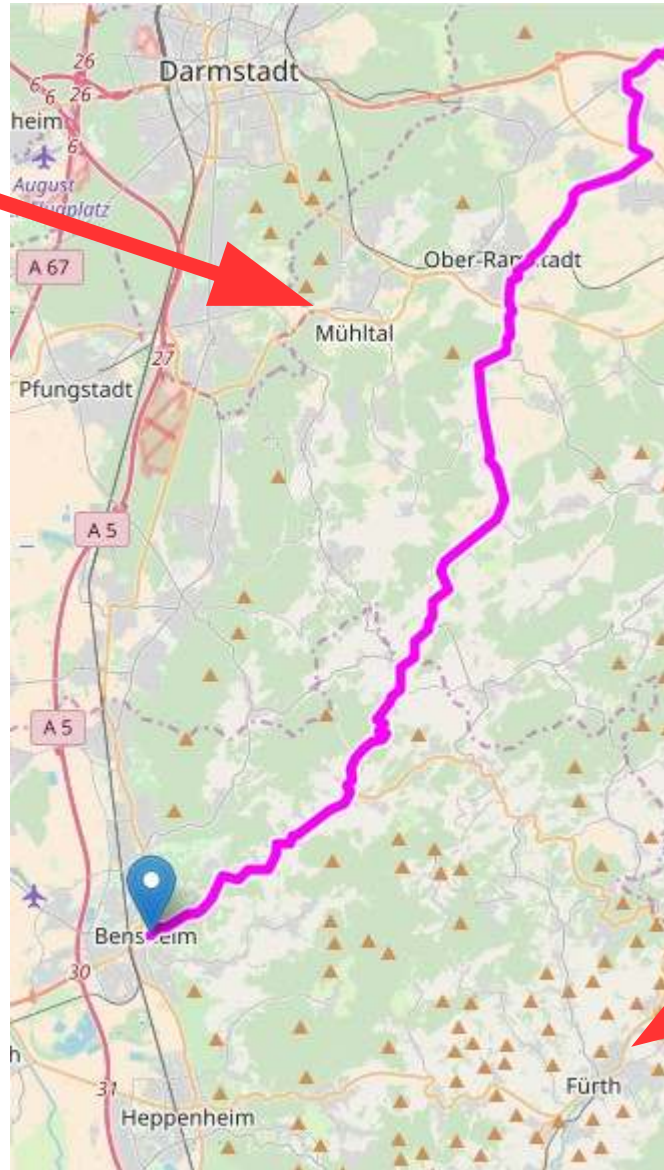
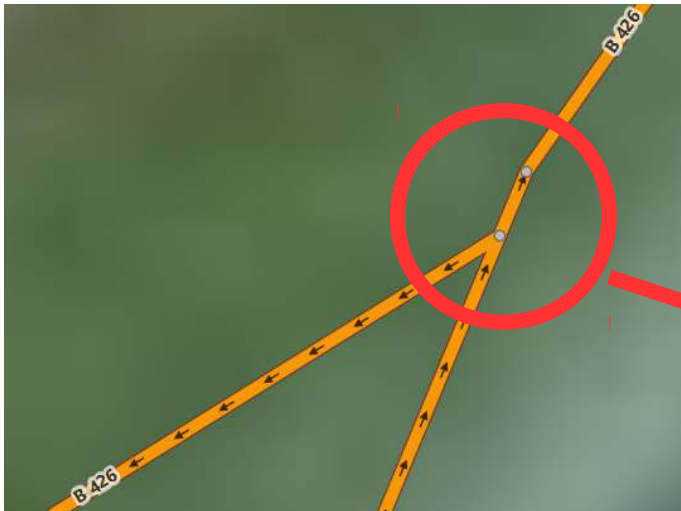
~~B 426~~



~~B 88~~



Connectivity? Status Quo 09/2017



2 Errors in 640 sqkm
==> ca. 1000 Errors
in Germany
(357.000 qkm)



QA Road-Network: Suspect Scanner / Manager

The image displays three browser screenshots of the 'Suspect Scanner / Manager' application. The browser address bar in all screenshots is 'brouter.de:443/brouter/suspects'.

Left Screenshot: Shows a list of countries with underlined links: [austria](#), [belgium](#), [bosniaherzegovina](#), [croatia](#), [czechia](#), [france](#), [germany](#), [germany_etr](#), [hungary](#), [luxembourg](#), [poland](#), [serbia](#), [slovakia](#), [slovenia](#), [switzerland](#), [thenetherlands](#). A green arrow points from the 'germany' link to the middle screenshot.

Middle Screenshot: Shows the 'suspect list for germany' with the following links: [see watchlist](#), [back to country list](#). Below this, it says 'current level: secondary' and lists 15 coordinate pairs, each with a blue underlined link: [7.770091,51.654872](#), [8.630739,49.866537](#), [8.631033,49.866603](#), [8.655798,49.991977](#), [8.65709,49.991296](#), [8.162019,50.84019](#), [8.169072,50.844596](#), [8.772501,50.807671](#), [8.773487,50.807586](#), [11.608742,48.117963](#), [11.618093,52.109905](#), [11.61994,52.110163](#), [11.620006,52.109493](#), [11.620073,52.109494](#), [11.620571,52.109696](#), [13.572893,51.210888](#), [13.587674,51.2008](#), [13.613796,51.288552](#). A green arrow points from the first coordinate link to the right screenshot.

Right Screenshot: Shows a list of action links for each suspect: [Open in BRouter-Web](#), [Open in OpenStreetmap](#), [Open in JOSM \(via remote control\)](#), [mark false positive \(=not an issue\)](#), [mark as a confirmed issue](#), and [back to issue list](#).

QA Road-Network: Suspect Scanner / Manager

The screenshot displays the BRouter web client interface. At the top, there is a menu bar with options: Datei, Bearbeiten, Ansicht, Chronik, Lesezeichen, Extras, Hilfe. Below the menu is a browser window titled "BRouter web client" with the address bar showing "brouter.de/brouter-web/#zoom=18&lat=51.654872&lon=7.770091&layer=OpenStreetM...". The main interface is divided into several sections:

- BRouter-Web 0.6.3**: Includes instructions: "'esc' or 'q' to disable drawing, 'd' to enable drawing" and "Web client for BRouter · work in progress · about".
- Options**: Profile: <custom>, Alternative: original.
- Route**: Length: 0 km, Ascent filtered: 0 m, Ascent plain: 0 m, Cost: 0, Mean cost: 0.
- Download**: A graph showing elevation in meters (m) on the y-axis (0.0 to 1.0) and distance in meters (m) on the x-axis (0.0 to 1.0).
- Profile Data**: A text area containing routing parameters: "# Car-Routing based on a kinematic model", "# Depending on the vmax-parameter (target-speed)", and "#". Below the text area are buttons for Upload, Clear, and Help.

The map shows a road network with a highlighted route. Key roads include Flozstraße, Kamener Straße, and Zum Bergwerk. A blue location pin is placed on the route. The map includes a scale bar (30 m, 100 ft) and a "Permalink" link at the bottom right. The footer text reads: "Leaflet | BRouter © Arndt Brenschede, routing + map data © OpenStreetMap contributors (ODbL), tiles © OpenStreetMap contributors, search by Nominatim".

QA Road-Network: Suspect Scanner / Manager

BRouter-Web 0.6.3
'esc' or 'q' to disable drawing, 'd' to enable drawing
Web client for [BRouter](#) · work in progress · about

Options
Profile:
Alternative:

Route

Length:	4.8 km
Time:	9 min
Energy:	0.5 kWh (mean: 10.44)
Ascent:	12 m (plain: 1)
Cost:	8488 (mean: 1.77)

Download [GPX](#) · [KML](#) · [GeoJSON](#) · [data CSV](#)

Profile Data

```
## Car-Routing based on a kinematic model
## Depending on the umax-parameter (target-transect)
```

[Upload](#) [Clear](#) [Help](#)

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Outlook / TODOs

- implement road network QA world-wide
- Update BRouter integration in popular MapTools:

Name	Turning-Hints	Time of Arrival	Street-names	Direction-Hints	Lane-mapping
LocusMaps Pro	o.k	Almost done	missing	n.a.	n.a
OsmAnd Plus	missing	missing	missing	missing	missing
OruxMaps	n.a.	n.a	n.a	n.a	n.a

- ... Integrated driving assistance for electric cars ?

Thank you!

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