

# Energieeffizientes PKW-Routing mit OpenStreetMap

- Schnell und sparsam ans Ziel -

FOSSGIS 2018 – Bonn – 22.3.2018

- Dr. Arndt Brenschede -

# B(ike?)Router ?

- 01 / 2013 Veröffentlichung BRouter
- ....
- 01 / 2014 erstes, experimentelles Auto-Routing
- ....
- 05 / 2016 Abbiege-Hinweise
- 12 / 2016 Abbiege-Beschränkungen
- 09 / 2017 Kinematisches Modell
- 10 / 2017 Map-QS Strassennetz



brauchbares Auto-Routing

# Status Quo

Autobahnlastige, rein nach Fahrzeit optimierte Routen dominieren den Markt.  
Beispiel mit OSRM von Stuttgart nach Luxemburg, **Ziel im Norden der Stadt:**

**351 km, 3:26 Stunden**

The screenshot shows the OpenStreetMap routing interface. At the top, the 'OpenStreetMap' logo is on the left, and navigation options 'Bearbeiten', 'Chronik', and 'Export' are in the center. On the right, there are links for 'Mehr', 'Anmelden', and 'Registrieren'. Below the header, a search bar on the left contains the coordinates '48.7204, 9.1475' and '49.629, 6.158', with a dropdown menu set to 'Auto (OSRM)' and a blue 'Los' button. The main map area displays a blue route starting from Stuttgart (marked with a green pin) and ending at Luxembourg (marked with a red pin). The route passes through Karlsruhe, Mannheim, Kaiserslautern, Trier, and Metz. The map includes labels for various cities and regions like 'Rheinland-Pfalz', 'Saarland', 'Saarbrücken', 'Metz', 'Nancy', 'Strasbourg', 'Heilbronn', 'Pforzheim', 'Heidelberg', 'Darmstadt', and 'Mainz'. A scale bar at the bottom left indicates 30 km and 20 miles. The bottom right corner features the copyright notice '© OpenStreetMap-Mitwirkende' and a 'Spenden' button.

**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 470m

# Status Quo

Autobahnlastige, rein nach Fahrzeit optimierte Routen dominieren den Markt.  
Beispiel mit OSRM von Stuttgart nach Luxemburg, Ziel **Stadtmitte**:

**313 km, 3:25 Stunden (-38 km, gleiche Fahrzeit )**

**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

© OpenStreetMap-Mitwirkende Spenden

# Zielfunktion im Routing:

$$\textit{Kosten} = \textit{Zeit}$$

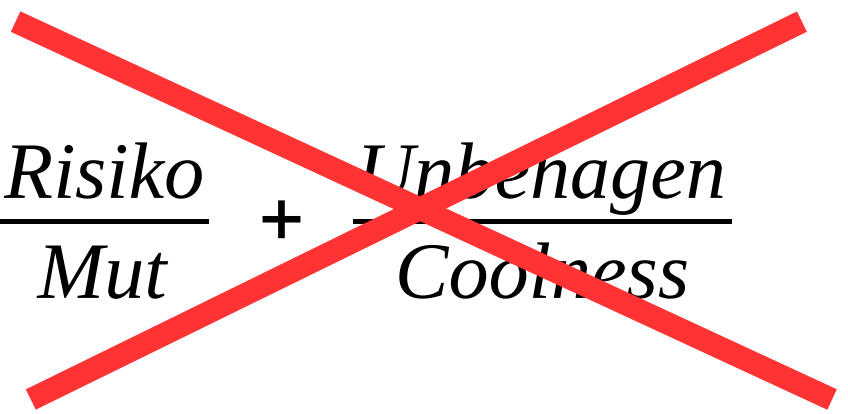
# Zielfunktion im Routing:

$$\textit{Kosten} = \textit{Zeit} + \frac{\textit{Energie}}{P_{\textit{weight}}}$$

# Zielfunktion der Zielgruppe:

$$Kosten = Zeit + \frac{Energie}{P_{weight}} + \frac{Risiko}{Mut} + \frac{Unbehagen}{Coolness}$$

# Zielfunktion im Energie-effizienten Routing:

$$\text{Kosten} = \text{Zeit} + \frac{\text{Energie}}{P_{\text{weight}}} + \frac{\text{Risiko}}{\text{Mut}} + \frac{\text{Unbenagen}}{\text{Coolness}}$$


$$P_{\text{weight}} = \text{Energie} / \text{Zeit Gewichtung ( gemessen in kW)}$$



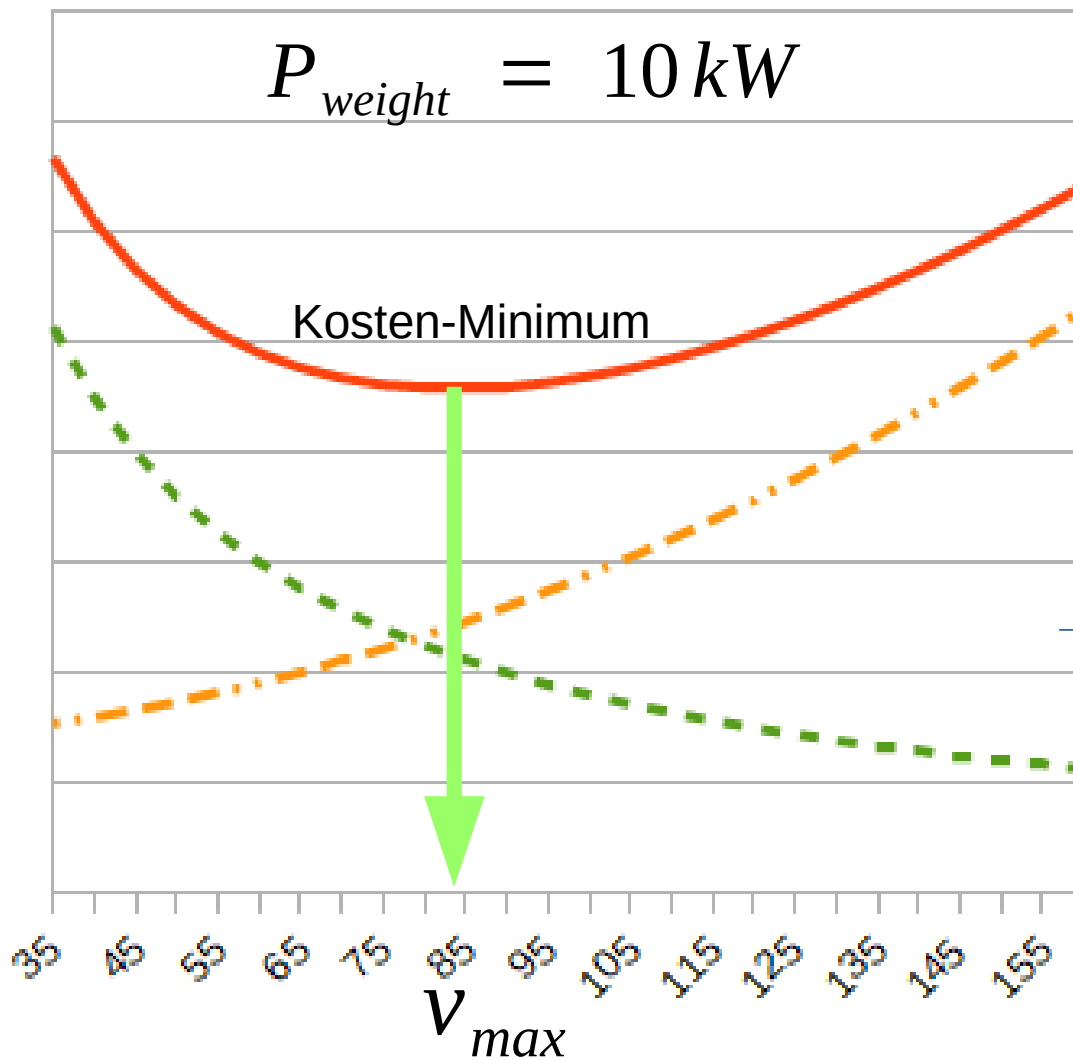
# Angabe der Energiespar-Präferenz

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

# Angabe der Energiespar-Präferenz

V-max (km/h)	P-charge (kW)	E-Mobil V-Avg Incl. Ladestops (km/h)
61	3,7	21
89	11	41
110	22	58
<b>120</b>	<b>28,6</b>	
144	50	84

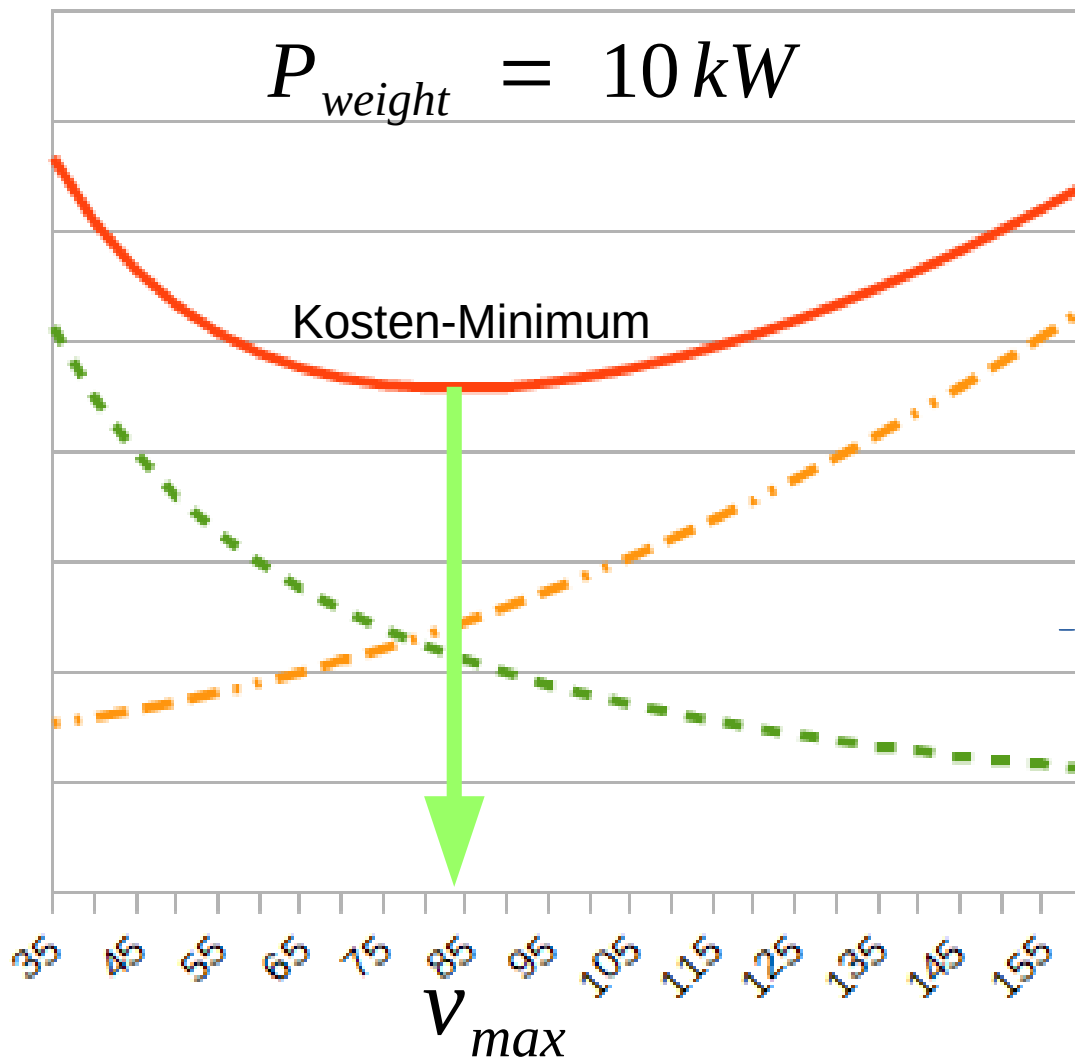
# Äquivalenz von $P_{weight}$ und $v_{max}$ !



$$\text{Kosten} = \text{Zeit} + \frac{\text{Energie}}{P_{weight}}$$

- Energieteil
- - - Zeitanteil
- Gesamt

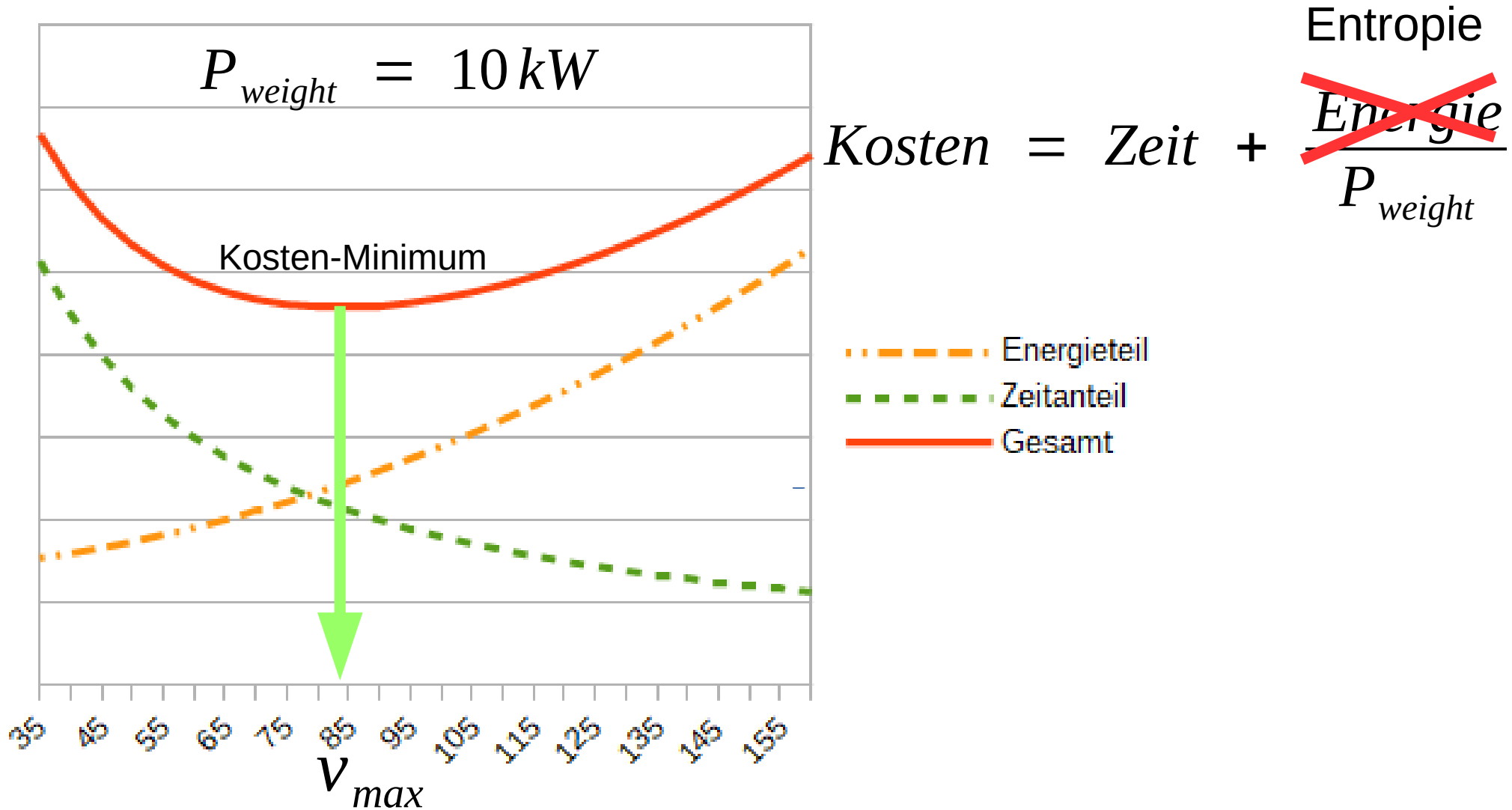
# Äquivalenz von $P_{weight}$ und $v_{max}$ !



$$\text{Kosten} = \text{Zeit} + \frac{\text{Energie}}{P_{weight}}$$

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

# Äquivalenz von $P_{weight}$ und $v_{max}$ !



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

# Routing abhängig von der Energiespar-Präferenz

Aschaffenburg → Bensheim  $V_{max} = 160 \text{ km/h} \implies 52 \text{ Minuten, } 23 \text{ kWh}$

**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 = 250 # Watt
```

5 km 5 mi

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

# Routing abhängig von der Energiespar-Präferenz

Aschaffenburg → Bensheim  $V_{max} = 120 \text{ km/h} \implies 72 \text{ Minuten, } 9 \text{ kWh}$

**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 abhängig von der Energiespar-Präferenz

Aschaffenburg → Bensheim  $V_{max} = 60 \text{ km/h} \implies 83 \text{ Minuten, } 6,5 \text{ kWh}$

**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: 61.1 km  
Time: 82.9 min  
Energy: 6.46 kWh (mean: 10.57)  
Ascent: 289 m (plain: -21)  
Cost: 71420 (mean: 1.17)

**Download** GPX · KML · GeoJSON · data CSV

**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

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# Routing abhängig von der Energiespar-Präferenz

Aschaffenburg → Bensheim  $V_{max} = 60 \text{ km/h} \implies 83 \text{ Minuten}, 6,5 \text{ kWh}$

**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: 87.1 km  
Time: 82.9 min  
Energy: 6.46 kWh (mean: 10.57)  
Cost: 71420 (mean: 1.17)

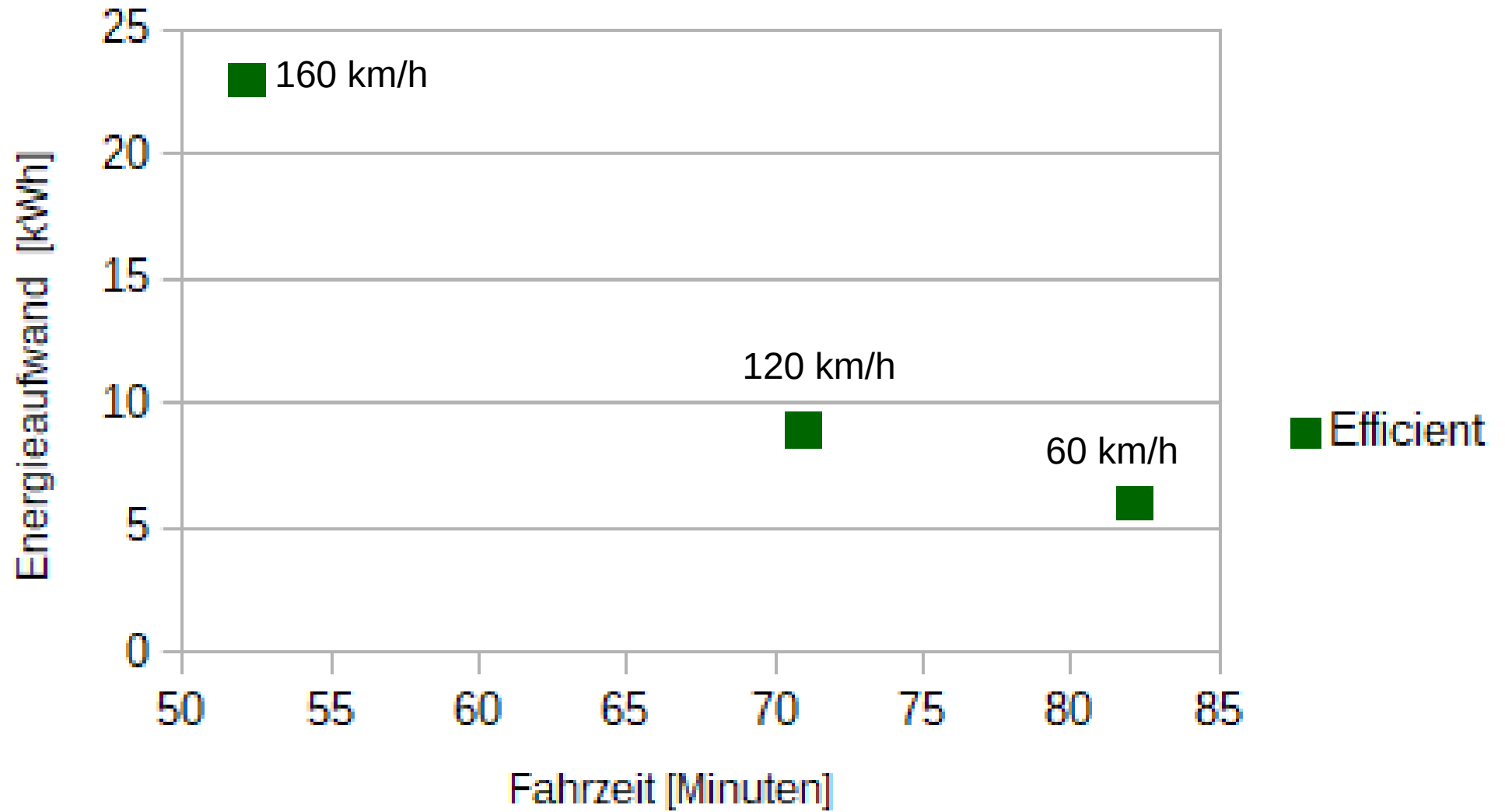
**Download** GPX · KML · GeoJSON · data CSV

**Profile Data**

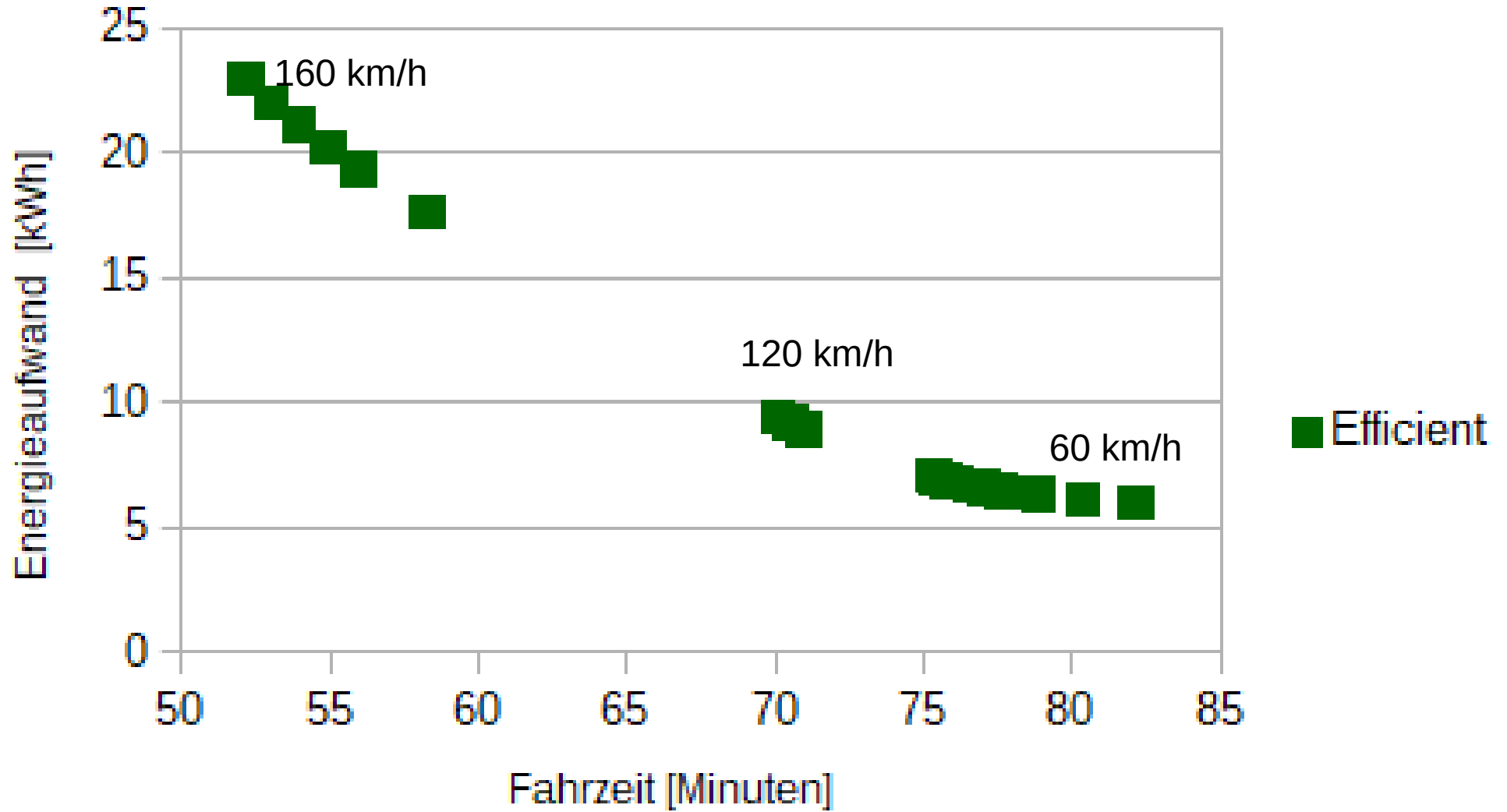
```
# kinematic parameters
assign vmax = 60 # kmh
assign recup_efficiency = 0.7 # (ratio)
assign totalweight = 1640 # kg
assign f_roll = 232 # Newton
assign f_air = 0.4 # 0.5*cw*A*rho
assign f_recup = 400 # Newton
assign p_standby = 250 # Watt
```

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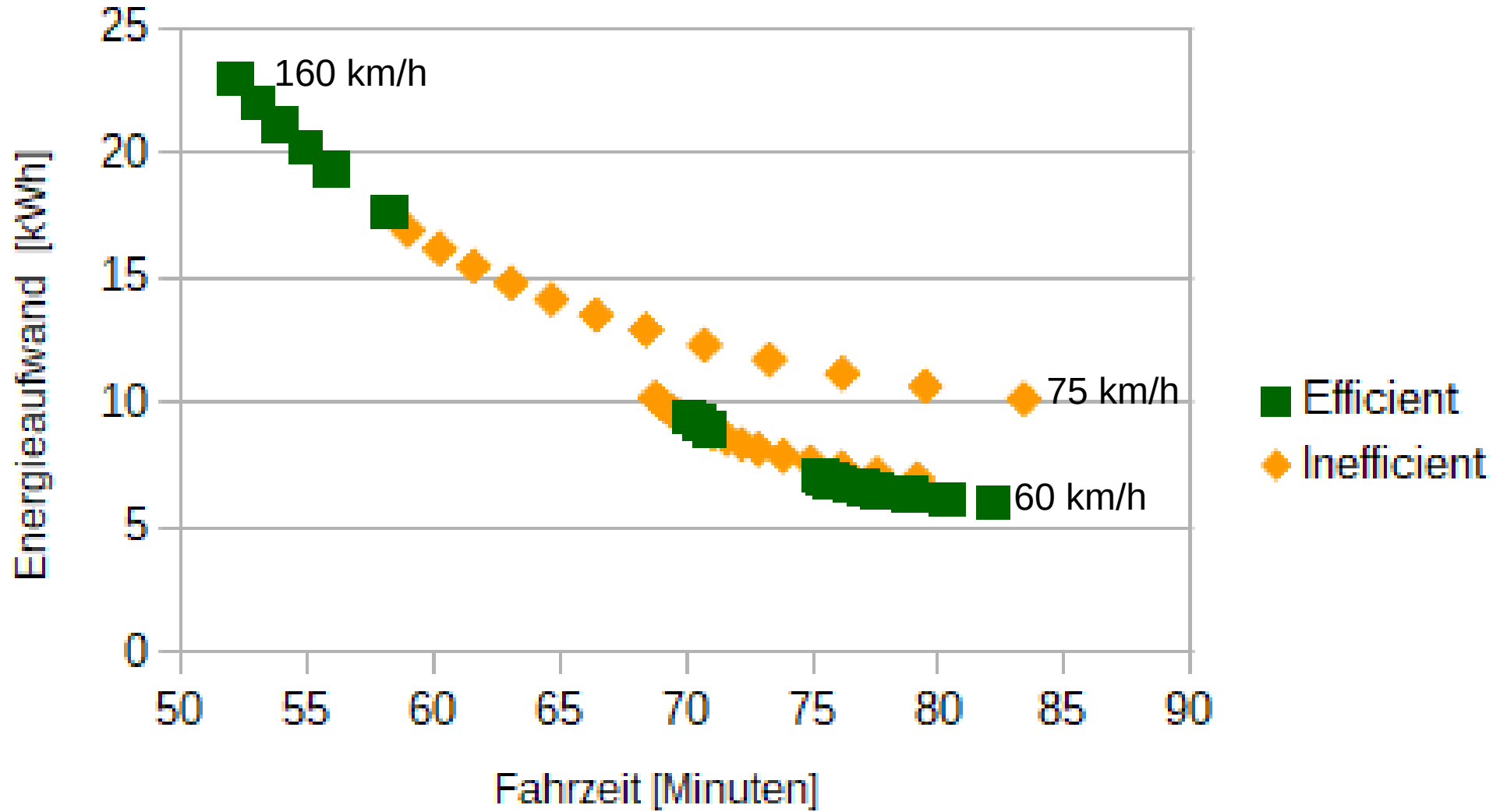
# Energie – Zeit Diagramm



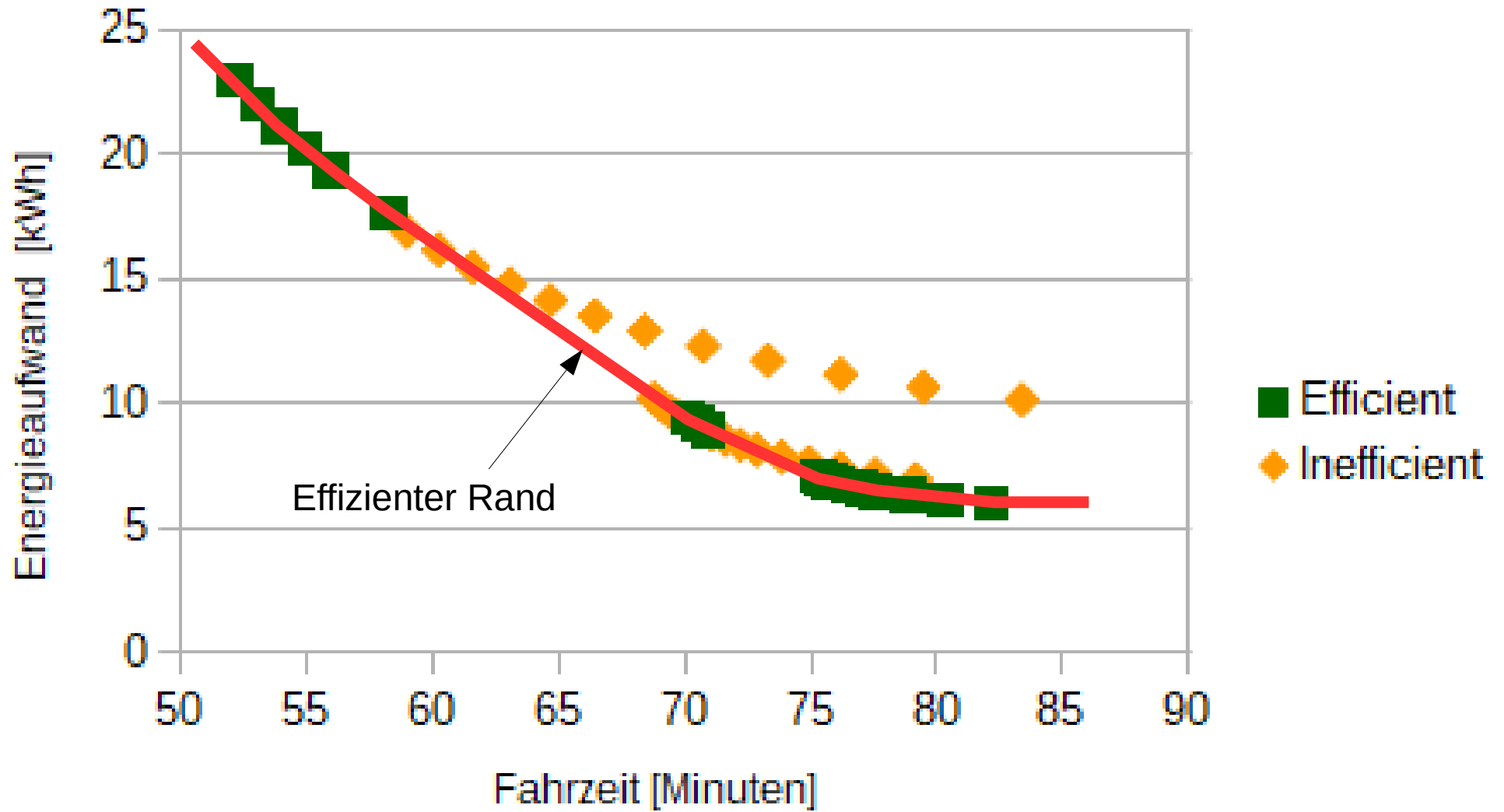
# Energie – Zeit Diagramm



# Energie – Zeit Diagramm

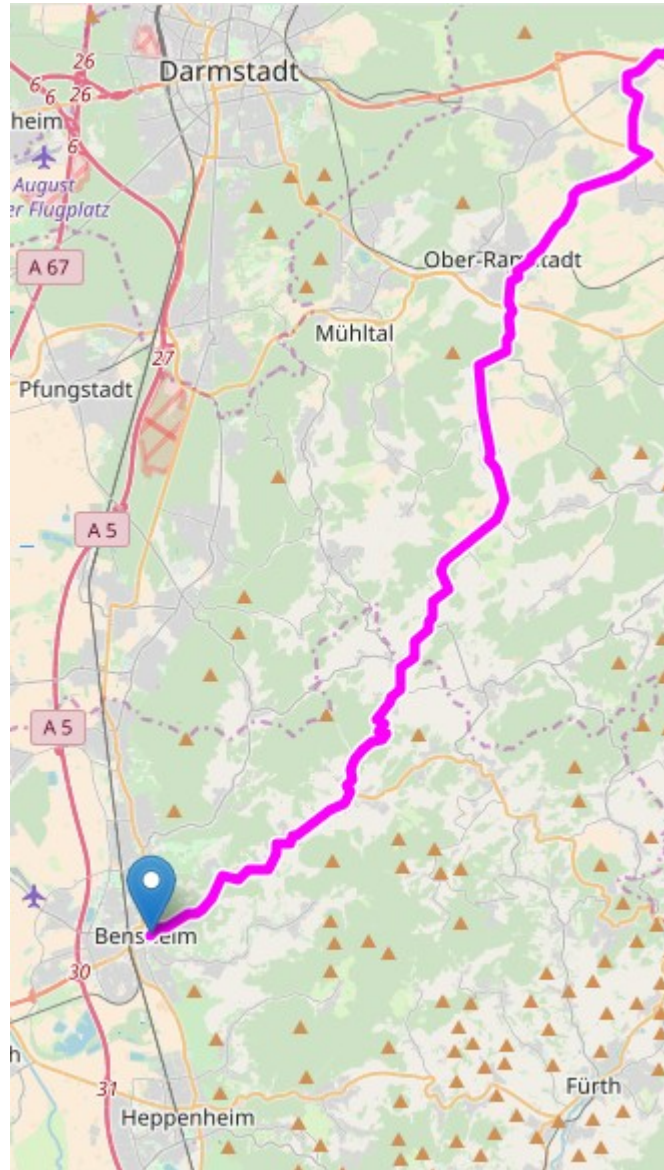


# Energie – Zeit Diagramm

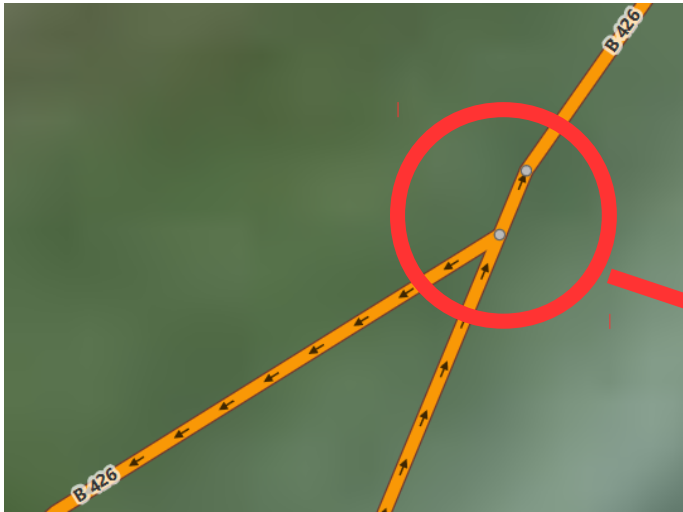


# Soll ich's wirklich machen?

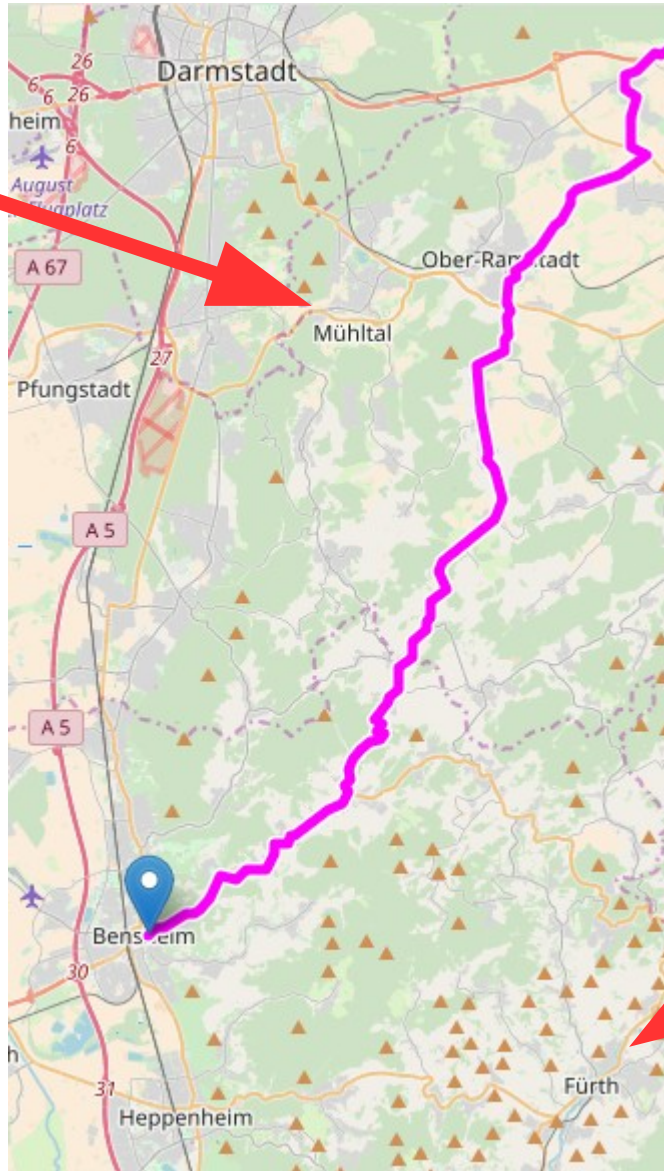
- oder sind im Wald die Räuber? -



# Connectivity? Status Quo 09/2017



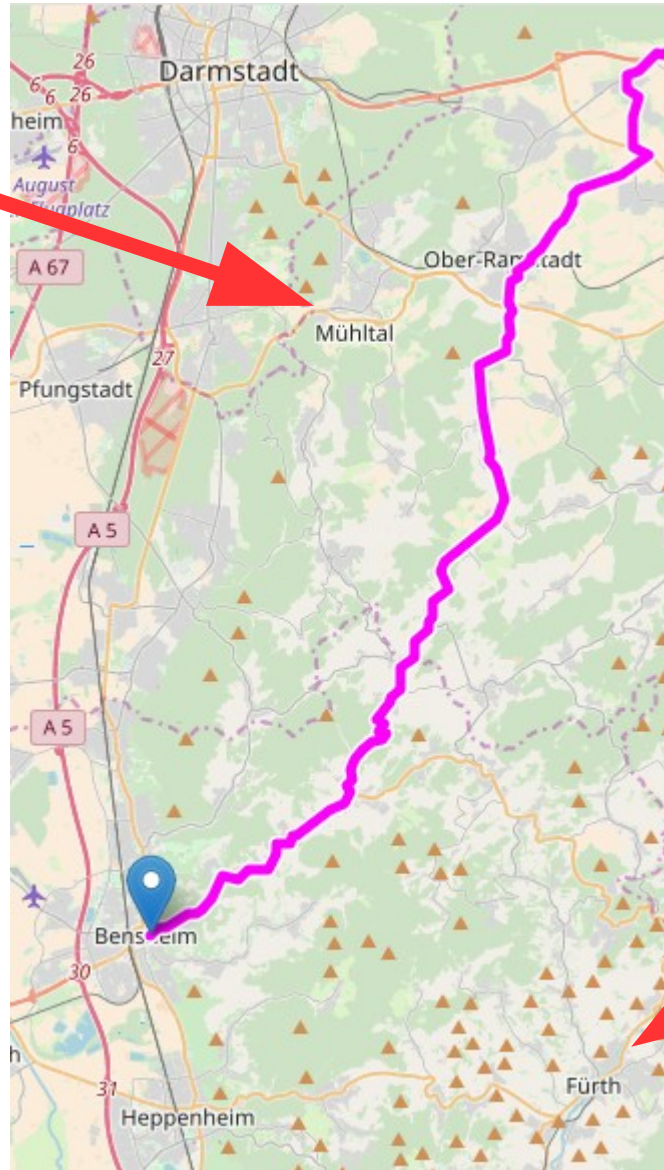
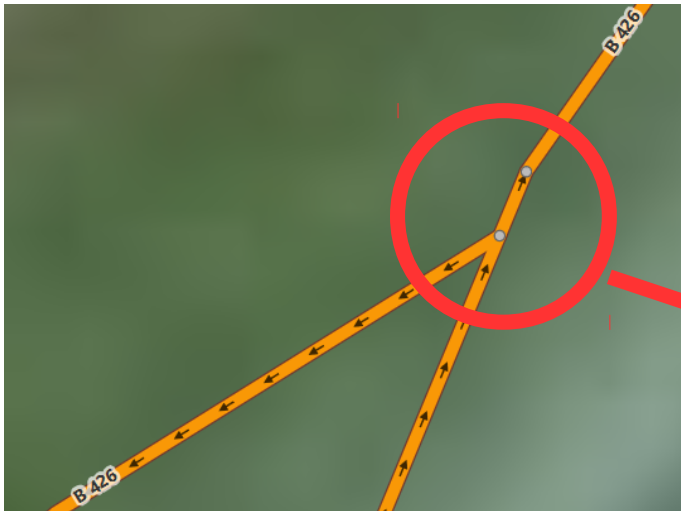
~~B 426~~



~~B 88~~



# Connectivity? Status Quo 09/2017



2 Fehler in 640 qkm  
==> ca. 1000 Fehler  
in Deutschland  
( 357.000 qkm )





# QS Fernwegenetz: Suspect Scanner / Manager

Menu: Datei Bearbeiten Ansicht Chronik Lesezeichen Extras  
Address bar: brouter.de:443/brouter/suspects

- [austria](#)
- [belgium](#)
- [bosniaherzegovina](#)
- [croatia](#)
- [czechia](#)
- [france](#)
- [germany](#)
- [germany\\_etr](#)
- [hungary](#)
- [luxembourg](#)
- [poland](#)
- [serbia](#)
- [slovakia](#)
- [slovenia](#)
- [switzerland](#)
- [thenetherlands](#)

Menu: Datei Bearbeiten Ansicht Chronik Lesezeichen Extras  
Address bar: brouter.de:443/brouter/suspects/ge

suspect list for germany  
[see watchlist](#)  
[back to country list](#)  
current level: secondary

- [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](#)
- [13.613796,51.288552](#)

Menu: Datei Bearbeiten Ansicht Chronik Lesezeichen Extras  
Address bar: brouter.de:443/brouter/suspects/ge

- [Open in BRouter-Web](#)
- [Open in OpenStreetmap](#)
- [Open in JOSM \(via remote control\)](#)
- [mark false positive \(=not an issue\)](#)
- [mark as a confirmed issue](#)
  
- [back to issue list](#)

# QS Fernwegenetz: 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 a search bar containing "Suchen".

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 a scrollable list of parameters.

The map shows a route highlighted in yellow, passing through "Zum Bergwerk" and "Kamener Straße". A blue location pin is placed on the route. The map includes a scale bar (30 m, 100 ft) and a "Permalink" button.

# QS Fernwegenetz: 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 wmax parameter (targettraced)  
  [Help](#)

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

The screenshot shows a web browser window with the BRouter web client. The browser address bar shows the URL: `brouter.de/brouter-web/#zoom=18&lat=51.654872&lon=7.770091&layer=OpenStreetMap`. The main interface features a sidebar on the left with route information and a map on the right. The route is highlighted in pink and yellow on the map, passing through a green field and a road labeled 'Kamener Straße'. A blue location pin is placed on the route. The sidebar includes a 'Route' section with statistics: Length: 4.8 km, Time: 9 min, Energy: 0.5 kWh (mean: 10.44), Ascent: 12 m (plain: 1), and Cost: 8488 (mean: 1.77). Below the route information is a 'Download' section with links for GPX, KML, GeoJSON, and data CSV. At the bottom of the sidebar, there is a 'Profile' section with a 'Data' tab and a text area containing routing parameters. The map shows a route starting from a blue location pin, passing through a green field, and ending at another blue location pin. The route is highlighted in pink and yellow. The map also shows a road labeled 'Kamener Straße' and a road labeled 'L 664'. A scale bar at the bottom indicates 30 m and 100 ft. The footer of the page contains the text: 'Leaflet | BRouter © Arndt Brenschede, routing + map data © OpenStreetMap contributors (ODbL), tiles © OpenStreetMap contributors, search by Nominatim'.

## Ausblick / TODOs

- QS Fernwegenetz europaweit implementieren

- Integration BRouter in den MapTools aktualisieren:

Name	Abbiege-Hinweise	Ankunftszeit	Strassen-namen	Richtungs-ansagen	Spur-mapping
LocusMaps Pro	<b>o.k</b>	<b>fehlt</b>	<b>fehlt</b>	n.a.	n.a
OsmAnd Plus	<b>fehlt</b>	<b>fehlt</b>	<b>fehlt</b>	<b>fehlt</b>	<b>fehlt</b>
OruxMaps	n.a.	n.a	n.a	n.a	n.a

- ... Integrierte Fahrassistenz für Elektroautos ?