

## Supporting Information

**Table S1**, Specific activities of enzyme preparations

<i>E. coli</i>	
<b>pIY003 (WT)</b>	
Evolution specific activity	0.91±0.10 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
Uptake specific activity	4.8±0.6 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
Relative activity after 85 °C, 1h	41% (std. err. 39-45%)*
Relative activity in 1% O <sub>2</sub>	29% (std. err. 21-35%)*
<b>pIY004 (H230C)</b>	
Evolution specific activity	0.50±0.05 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
Uptake specific activity	9.2±2.9 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
<b>pIY006(P285C)</b>	
Evolution specific activity	0.35±0.04 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
Uptake specific activity	7.7±1.2 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
<b>pIY007(H230C/P285C)</b>	
Evolution specific activity	3.3±0.4 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
Uptake specific activity	5.9±2.4 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
Relative activity after 85 °C, 1h	27% (std. err. 17-35%)*
Relative activity in ~1% O <sub>2</sub>	37% (std. err. 23-48%)*
Specific activity relative to pIY003	3.7±0.6
<b>pIY033(WT)</b>	
Evolution specific activity	1.6±0.3 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
<b>pIY038(H230C/P285C)</b>	
Evolution specific activity	3.8±0.5 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
Specific activity relative to pIY033	2.3±0.8
<b>pRC41-4(WT)</b>	
Evolution specific activity	9.1 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
<b>pCM012(H230C/P285C)</b>	
Evolution specific activity	19 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
<b>pIY085(WT, strep-tagged)</b>	
Evolution specific activity, unpurified	6.1 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
Evolution specific activity, purified	690 nmH <sub>2</sub> min <sup>-1</sup> (mg protein) <sup>-1</sup>
<b>pIY086(H230C/P285C, strep-tagged)</b>	
Evolution specific activity, unpurified	12.7 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
Evolution specific activity, purified	2200 nmH <sub>2</sub> min <sup>-1</sup> (mg protein) <sup>-1</sup>
Purified specific activity relative to pIY085	3.2
<i>S. elongatus</i>	
<b>pRC41-4(WT)</b>	
Evolution specific activity	0.10±0.01 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
<b>pCM012(H230C/P285C)</b>	
Evolution specific activity	0.54±.06 nmH <sub>2</sub> min <sup>-1</sup> (mg lysate) <sup>-1</sup>
Specific activity relative to pRC41-4	5.1±0.7

\*geometric standard error

**Table S2, Primers used in this study**

<b>Name</b>	<b>Sequence</b>	<b>Purpose</b>
<b>AMR3-2</b>	<b>CAATTTACACAGGAAACAGACCATGGATG</b> GCTTCCATTATTGGTAGC	Forward primer for amplification of hydrogenase operon starting at orf2 (light); overlaps with pTRC-NS1 (bold)
<b>AMR-44</b>	<b>TGCATGCCTGCAGGTCGACTCTAGAGGATC</b> TCAGCAGATCCTTGGGAAGC	Reverse primer for amplification of hydrogenase operon ending at hypE (light); overlaps with pTRC-NS1(bold)
<b>IY002HopMidF</b>	CCAGGCTACTCGAAGAAACG	Forward primer in the middle of hydrogenase operon
<b>IY003HopMidR</b>	GCGCACGTATCGTTTCTTCG	Reverse primer in the middle of the hydrogenase operon
<b>IY004HydSH238CF</b>	TGACAGATGTTATCGACGCC	Forward primer to generate H230C
<b>IY005HydSH238CR</b>	GGGCGTCGATAACATCTGT <b>CACAGATGCTT</b> TCACCAAAAAAG	Reverse primer to generate H230C mutation (bold)
<b>IY010pDEST24F</b>	GGCTGCTGCCACCGCTGAGC	Forward primer to amplify pDEST backbone
<b>IY011pDEST24R</b>	CTATAGTGAGTCGTATTAATTTTCGCGGG	Reverse primer to amplify pDEST backbone
<b>IY012HydT7CBAF</b>	<b>CCCGCAAATTAATACGACTCACTATAGGG</b> AAACAGACCATGGATGGC	Forward primer to amplify hydrogenase operon for insertion into pDEST24; overlaps with IY011pDEST24R (bold)
<b>IY013HydT7CBAR</b>	<b>GCTCAGCGGTGGCAGCAGCCAGGATCTCAG</b> CAGATCCTTGG	Reverse primer to amplify hydrogenase operon for insertion into pDEST24; overlaps with IY010pDEST24F (bold)
<b>IY014pDEST24F</b>	CCCGCAAATTAATACGACTCACTATAG	Forward primer to amplify hydrogenase operon out of pDEST24 plasmid
<b>IY015pDEST24R</b>	CTCGGAGCACTGTCCGACCGC	Reverse primer to amplify hydrogenase operon out of pDEST24 plasmid
<b>IY016NS1pDEST24F</b>	<b>GCGGTCCGACAGTGCTCCGAGCGAGCTTCT</b> GGAGCAGGAAG	Forward primer to amplify pTRC-NS1 for insertion of T7-driven hydrogenase; overlaps with IY015pDEST24R(bold)
<b>IY017NS1pDEST24R</b>	<b>CTATAGTGAGTCGTATTAATTTTCGCGGGCC</b> GATCCTCTAGTATGCTTGTAACC	Reverse primer to amplify pTRC-NS1 for insertion of T7-driven hydrogenase; overlaps with IY014pDEST24F(bold)
<b>IY018HydSP293CF</b>	ATCGAATCTGGCCATCCGTGT	Forward primer to generate P285C
<b>IY019HydSP293CR</b>	ACACGGATGGCCAGATTCGAT <b>ACAAAACT</b> CGTGCCTTG	Reverse primer to generate P285C mutation (bold)
<b>IY170HynSF</b>	GTATTATTGCCATCGGTACC	Forward primer upstream of BamHI site to transfer mutants
<b>IY171HynSR</b>	CGAGTGATAGGATCGACGAC	Reverse primer downstream of AgeI site to transfer mutants
<b>AN000StrepF</b>	CGTAGCGCTTGGTCCCACCCGAGTTCGAA <b>AAATAAGATAATAGGCAAGGCTCATGG</b>	Forward primer encoding the HynS C-terminal strep-tag; overlaps with hynS-hynL intergenic region (bold)
<b>AN001StrepR</b>	TTTTTCGAAGTGGGTTGGGACCAAGCGCT ACGTGAGTTTTT <b>CCAGCATGCTTC</b>	Reverse primer encoding the HynS C-terminal strep-tag; overlaps with the c-terminus of hynS (bold)

**Table S3 (22pp)**, Maps and sequences for vectors used in this study

Map Key:

Green – replication origins, transfer origins, transcriptional promoters

oriV – vegetative origin from p15

oriT – RP4 conjugation transfer origin

PTRC – P<sub>TRC</sub> promoter (includes lacO repressor element)

PT7 – P<sub>T7</sub> promoter

lacO – lacO repressor element

Red – transcriptional terminators, mutations

T4t – T4 terminator

rrnBt – rrnB terminator

Grey – upstream and downstream NS1 homology regions for transfer into *S. elongatus*

Yellow – ORFs









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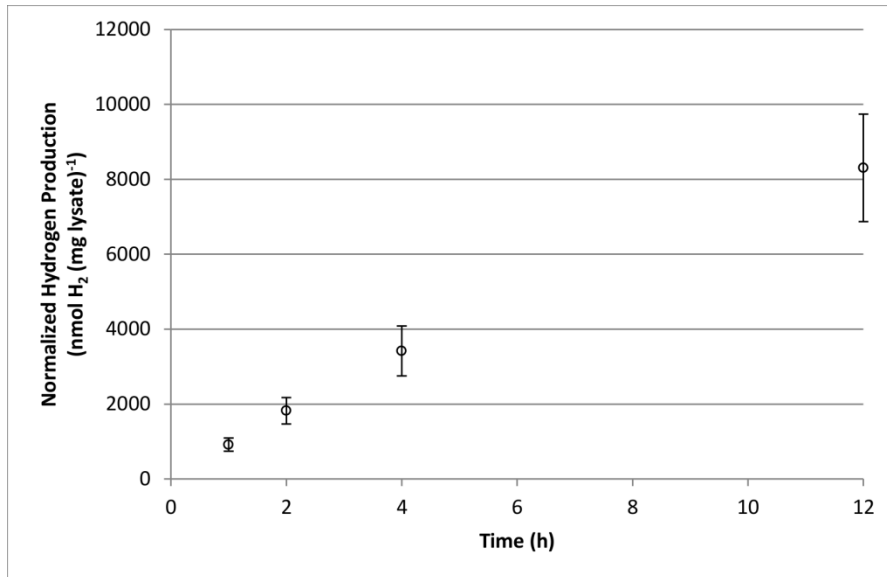








**Figure S1,** A representative enzyme activity progress curve over four hours, using the doubly substituted enzyme expressed in BL21 $\Delta$ H<sub>4</sub> cells. Data points represent three technical replicates of an experiment conducted using the procedures described in the methods section. There is some deviation from linearity at 12h, likely due to consumption of reductive potential.



**Figure S2,** Specific activities of samples from western blot experiment (bars correspond to samples from gel lanes as found in main text Fig. 4)

